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Project/Task WAG-7 Pits and Trenches RI/FS
Subtask Hydraulic Characterization Data: Sediments

TITLE: SDA Hydraulic Characterization Data Compilation: Surficial Sediments and Interbeds

SUMMARY

The summary briefly defines the problem or activity to be addressed in the EDF, gives a summary of activities performed in addressing the problem and states the conclusions, recommendations, or results arrived at from this task.

This report is a compilation of suface and interbed sediments hydraulic characteristic data for the Subsurface Disposal Area (SDA) Radioactive Waste Management Complex (RWMC). The major objective of the report is to generate one document that contains the hydraulic characteristics information needed by the modelers to simulate flow and contaminant transport beneath the RWMC. Not all the information in the references could be put into this document; therefore, a section on the abstracts of key references is included to help lead the modelers to more detailed information when needed. The report is primarily tables recreated from tables in related references. Many of the details explaining the information in the tables must be found in the references; however, there is some explanation included that was prepared in a previous RWMC physical characteristics study that has not been published and some of the references where an electronic version is available.

The report is divided into the following four sections;

1. Introduction
2. Abstracts of key references
3. Hydraulic characteristic data
4. References

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SDA Hydraulic Characterization Data Compilation: Surficial Sediments and Interbeds

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1.0 INTRODUCTION

This report is a compilation of surface and interbed hydraulic characteristic data for the Subsurface Disposal Area (SDA) at the Radioactive Waste Management Complex (RWMC). The major objective of the report is to generate one document that contains the surface and interbed hydraulic characteristics information needed by the modelers to simulate flow and contaminant transport beneath the RWMC. The report is primarily tables recreated from tables in related references. Many of the details explaining the information in the tables must be found in the references; however, there is some explanation included that was prepared in a previous RWMC physical characteristics study that has not been published, as well as text from some references where electronic copies are available. The text that is included is intended to support the tables and is copied (for the most part) from the reports. Minor modifications to the text have been made where appropriate.

The report is divided into the following four sections;

1. Introduction
2. Abstracts of key references
3. Hydraulic characteristic data
4. References

2.0 ABSTRACTS OF KEY REFERENCES

A lot of data has been collected to characterize the hydraulics of the surficial sediments and the interbeds. However, the information is distributed over a multitude of documents. This section is primarily the abstracts for the most important documents. It also includes some minor notes. The abstracts have been lifted directly from the reports with only minor modifications.

The information is provided here as an easy reference location both for people currently working on the SDA modeling and those who in the future will need a summary of the work completed. Not all the information in the references could be put into this document; therefore, this section can help lead those interested to more detailed information when needed.

Barraclough, J. T., J. B. Robertson and V. J. Janzer, 1976. *Hydrology of the Solid Waste Burial Ground, as Related to the Potential Migration of Radionuclides, Idaho National Engineering Laboratory*, IDO-22056 and USGS Open-File Report 76-471.

This report describes the results of a study made in 1970-1974 to evaluate the geohydrologic and geochemical controls on subsurface migration of radionuclides from pits and trenches in the Idaho National Engineering Laboratory (INEL) solid waste burial ground and to determine the existence and extent of radionuclide migration, if any, from the burial ground. A total of about 1,700 sediment, rock, and water samples were collected from 10 observation wells drilled in and near the burial ground of Idaho National Engineering Laboratory, formerly the National Reactor Testing Station (NRTS).

Within the burial ground area, the subsurface rocks are composed principally of basalt. Wind- and water-deposited sediments occur at the surface and in beds between the thicker basalt zones. Two principal sediment beds occur at about 110 feet (34 metres) and 240 feet (73 metres) below the land surface. The average thickness of the surficial layers is about 15 feet (4.6 metres) while that of the two principal subsurface layers is 13 and 14 feet (4.0 and 4.3 metres), respectively. The water table in the aquifer beneath the burial ground is at a depth of about 580 feet (177 metres).

Fission, activation, and transuranic elements were detected in some of the samples from the 110- and 240-foot (34- and 73-metre) sedimentary layers. Although some of the observed concentrations might be the result of statistical variance or artificial sample contamination, some migration of nuclides from the burial ground has apparently resulted from infiltration of precipitation and runoff water which, on occasion, flooded burial ground pits and trenches.

Borghese, J. V., 1988. *Hydraulic Characteristics of Soil Cover, Subsurface Disposal Area, Idaho National Engineering Laboratory*, Masters Thesis, Department of Geology and Geological Engineering, University of Idaho, Moscow, Idaho 83843. Prepared for EG&G Idaho, Inc. Under Subcontract No. C85-110544.

Hydraulic characteristics of the soil cover at the Subsurface Disposal Area are examined. Laboratory methods are used to determine the characteristics of: saturated hydraulic conductivity (K), grain size distribution, dry bulk density, and porosity. The range of saturated vertical hydraulic conductivity of the samples tested is 7.7×10^{-6} to 8.4×10^{-2} cm/s. The analysis of grain sizes indicate that the samples are predominantly silt size. Dry bulk densities range from 1.0 to 1.5 g/cm^3. Laboratory porosity values ranged from 25 to 38 percent. The highest K values were determined for a depth interval of about 5 to 15 cm below land surface for 45 percent of the tested samples. A depth of about 15 to 25 cm has the highest bulk density for 60 percent of the tested samples.

Daniel B. Stephens & Associates, Inc., 1989, *Laboratory Analysis of Soil Hydraulic Properties From EG&G's BWP-RWMC Project*, Prepared for EG&G Idaho, Inc., November.

Daniel B. Stephens & Associates, Inc. (DBS&A) was requested by Ms. Debbie McElroy of EG&G Idaho, Inc. in Idaho Falls, Idaho to perform laboratory analysis of physical and hydraulic properties of soil samples, as outlined in the written communication of August 23, 1989. The scope of work included conducting the following tasks:

1. Sample preparation
2. Saturated hydraulic conductivity
3. Initial moisture content, dry bulk density and porosity
4. Moisture characteristics
5. Calculated and measured unsaturated hydraulic properties
6. Particle size distribution
7. Particle density

Hertzler, C. L. and G. A. Harris, 1989, *Statistical Analysis of Radioactive Waste Management Complex Matric Potential Data*, Letter Report, CLH-07-89, EG&G Idaho, Inc.

This report summarizes the statistical analysis of the matric potential data collected at the Radioactive Waste Management Complex (RWMC) at the Idaho National Engineering Laboratory (INEL) from May, 1985 to September, 1988. Matric potential (ψ_m) was measured in 25 wells in or near the Subsurface Disposal Area (SDA) of the RWMC. The ψ_m were measured at various depths within each well. Depths were measured from the surface and do not represent absolute elevations. Several instrument types were used to measure the ψ_m; these instruments were tensiometers, gypsum blocks, heat dissipation devices, and psychrometers.

Specifically, this report addresses four objectives. The first objective was to validate the raw data. The second objective was to assess the reliability of the various instrument types. The third objective was to determine if there is a ψ_m gradient over depth within a well. The final objective was to group wells together based on their ψ_m profiles.

(From page 17.) The results of the cluster analyses were extremely consistent. Although the number of clusters ranged from 2 to 5, 67% of the analyses resulted in 3 clusters. The wells composing each of the clusters was also consistent. Two of the 3 clusters were indicators of "wet wells" and "dry wells". The wet wells (high ψ_m) were PA1, PA2, T23, W02, W05, W06, W09, W20, W24, and W25. The dry wells (low ψ_m) were W10, W11, W13, W17, and W18. The third cluster was solely composed of well W19. This well was extremely dry compared to the other wells, except in the 11 to 30 ft. strata where it was relatively moist.

Notes:
1. There was no abstract for this report, so parts of a summary of the introduction and results has been substituted for the abstract.
2. It is difficult to identify which portions of this report may be useful to the modelers. Therefore, none of the data is incorporated into this report.

Hubbell, J. M., L. C. Hull, T. G. Humphrey, B. F. Russell, J. R. Pittman, and K. M. Caanan, 1985, *Annual Progress Report: FY-1985, Subsurface Investigations Program at the Radioactive Waste Management Complex of the Idaho National Engineering Laboratory*, DOE/ID-10136.

This report describes work conducted in FY-95 in support of the Subsurface Investigations Program at the Radioactive Waste Management Complex of the Idaho National Engineering Laboratory. The work is part of a continuing effort to define and predict radionuclide migration from buried waste. The Subsurface Investigations Program is a cooperative study conducted by EG&G Idaho and the U. S. Geological Survey, INEL Office. EG&G is responsible for the shallow drilling, solution chemistry, and net downward flux portions of this program, while the U. S. Geological Survey is responsible for the weighing lysimeters and test trench. Data collection was initiated by drilling, sampling, and instrumenting shallow wells, continuing the installation of test trenches, and modifying the two weighing lysimeters.

Twenty-one auger holes were drilled around the Radioactive Waste Management Complex (RWMC) to evaluate radionuclide content in the surficial sediments, to determine the geologic and hydrologic characteristics of the surficial sediments, and to provide as monitoring sites for moisture movement in these sediments. Eighteen porous cup lysimeters were installed in 12 auger holes to collect soil water samples from the surficial sediments. Fourteen auger holes were instrumented with tensiometers, gypsum blocks and/or psychrometers at various depths throughout the RWMC. Readings from these instruments are taken on a monthly basis.

Notes: Most of the data is in the appendices
1. Appendix A is the geologic description of the core samples.
2. Appendix B is the field chemistry measurements of RWMC soil water samples.
3. Appendix C is the well completion diagrams.
4. This is the first in a series of four annul progress reports on the Subsurface Investigations Program at the RWMC. See Hubbell, et al. 1986, Laney, et al. 1988, and McElroy, et al. 1989.

Hubbell, J. M., L. C. Hull, T. G. Humphrey, B. F. Russell, J. R Pittman, and P. R. Fisher, 1986, *Annual Progress Report: FY-1986, Investigations Program at the Radioactive Waste Management Complex of the Idaho National Engineering Laboratory,* DOE/ID-10153, 69 pp.

This report describes work conducted in FY-96 in support of the Subsurface Investigations Program at the Radioactive Waste Management Complex (RWMC) of the Idaho National Engineering Laboratory. The work is part of a continuing effort to define and predict radionuclide migration from buried waste. The objectives of this program are to develop a field calibrated computer model to predict the long-term migration of radionuclides in the unsaturated zone and to measure the actual migration of radionuclides to date. Eleven shallow auger holes were drilled in and around the RWMC to evaluate radionuclide content in the surficial sediments, to determine the geologic and hydrologic characteristics of the surficial sediments, and to provide monitoring sites for moisture movement in these sediments. One hundred twelve samples were collected. All auger holes were instrumented with tensiometers, porous cup lysimeters , heat dissipation sensors, and/or psychrometers at depths of 2 to 20 ft. Readings from these instruments are taken on a monthly basis. Deep drilling procedures for sample collection and soil moisture monitoring installation were prepared and reviewed. Three deep drill holes were drilled within the Subsurface Disposal Area. One of the drill holes was instrumented with lysimeters and heat dissipation sensors at two depths while being backfilled. The remaining two holes are cased and were sealed with waterproof locking caps. Sixteen surficial sediment samples, including 3 Shelby tube samples, were collected from the deep drill holes. Core samples from the weighing lysimeter site were evaluated in a pressure plate extractor. The weighing lysimeters were insulated and rewired to new multiplexors. Readings are recorded every six hours. Instruments were calibrated and installed in east test trench. Soil-water samples were collected from the surficial sediments and analyzed. The TRACR3D computer code was tentatively selected fro modeling at this site. Radiochemical analysis of FY-85 samples continued.

Notes: The appendices have the following data:
1. Appendix A has the geologic description of shallow drilling samples.
2. Appendix B has the geologic description of deep drilling samples.
3. Appendix C has the borehole completion diagrams.
4. This is the second in a series of four annul progress reports on the Subsurface Investigations Program at the RWMC. See Hubbell, et al. 1985, Laney, et al. 1988, and McElroy, et al. 1989.

Hughes, J. D., 1990, *Analysis of Characteristics of Sedimentary Interbeds at the Radioactive Waste Management Complex, Idaho National Engineering Laboratory, Idaho*, Master Thesis in Geology, Idaho State University, Pocatello, Idaho.

Three sedimentary layers have been identified interbedded within the basalt beneath the Radioactive Waste Management Complex (RWMC) at the Idaho National Engineering Laboratory (INEL) at depths of approximately 30 feet, 110 feet and 240 feet below the ground surface. These interbeds were deposited with basalt flows during the late Pleistocene approximately 50,000 to 450,000 years ago. Core obtained from 17 wells at the RWMC provided the majority of information for this study which attempts to define the sedimentologic properties and depositional environments of the sediments.

The 30-foot interbed ranges in thickness from 1.25 feet to 4.5 feet where it is present. This interbed is extremely discontinuous as it was encountered during the drilling of only 3 of 17 wells. The sediment consists primarily of very fine sand and silt and represents deposition in a floodplain environment.

The 110-foot interbed ranges in thickness from 2 to 32 feet where it is present. This interbed is not as laterally discontinuous as the 30-foot interbed as it is present in 14 of the 17 wells drilled at the RWMC. The 110-foot interbed consists almost entirely of sand and gravel. It is interpreted to have been deposited in a braidplain setting in channel systems up to 1000 feet wide between topographic highs in the basalt.

The 240-foot interbed is laterally continuous and up to 30 feet thick. This interbed was encountered in all wells drilled at the RWMC that were utilized in this study. This interbed consists primarily of sand and silt interpreted to have been deposited in low-energy channels and floodplains. The continuous nature of the sediments suggests deposition in a broad, shallow braidplain setting that aggraded to above the topographic highs in the basalt.

The sediments from the three interbeds most likely represent deposition from meltwater discharge associated with glacial declines. The 30-foot interbed was deposited approximately 50,000 to 100,000 years ago which suggests the deposits are pre-Pinedale in age. The 110-foot interbed was deposited around 100,000 to 225,000 years ago which correlates with ages of Bull Lake glacial features in the Idaho and Yellowstone Park vicinity. The 240-foot interbed is approximately 225,000 to 450,000 years in age which correlates with an episode of pre-Bull Lake glaciation documented in central Idaho.

Notes:
1. (Page 4) Core material came from 17 wells drilled by EG&G Idaho, Inc. between 1975 and 1988. The wells locations are shown in Figure 2.
2. (page 6) Samples were obtained for grain size analyses from each lithologically and/or texturally distinct bed as determined from the visual observations.
3. (page 8-10) Statistical data. Mean grain size, measure of uniformity or sorting, measure of asymmetry, measure of peakedness. The results of the statistics do not appear to be presented in the report.
4. Nice cross sections with qualitative data. Not very quantitative. The specifics (such as statistics) do not appear to be included in this report.
5. The information from the report is not included in this EDF because the data is more qualitative than quantitative.

Jorgensen, D. J., D. J. Kuhns, J. J. King, and C. A. Loehr, 1994, *WAG-7 Operable Unit (OU) 7-02 Acid Pit Track 2 Summary Report*, EGG-ERD-10242, EG&G Idaho, Inc.

The Environmental Restoration Department at EG&G Idaho, Inc., performed sampling of the interior of the Acid Pit in the Subsurface Disposal Area (SDA), in the Radioactive Waste Management Complex at the Idaho National Engineering Laboratory. The sampling and analysis of soil samples taken from the Acid Pit was conducted as a Track 2 study in support of the Federal Facility Agreement and Consent Order, which is currently arranged between the Department of Energy Idaho Operations Office, the Environmental Protection Agency, and the State of Idaho. The purpose of this site characterization activity was to determine the correct and final outcome for the Acid Pit, the options being: no further action, proceed to

an interim action, or folding the Acid Pit into a SDA remedial investigation/feasibility study. The recommendation for further action at the Acid Pit is included in this Summary Report.

Notes:
1. Appendix B has the physical and chemical properties of the Acid Pit soils. In the appendix are copies of tests performed on 35 soil samples in phase 1 and 18 soils samples in phase 2 (by Daniel B. Stephens & Associates, Inc.) Thirty two pages of summary tables for the moisture content, density, porosity, saturated hydraulic conductivity and unsaturated hydraulic properties are in the Appendix B but are not copied into this EDF.

Kaminsky, J. F., 1991, *In Situ Characterization of Unsaturated Hydraulic Properties of Surficial Sediments Adjacent to the Radioactive Waste Management Complex, Idaho National Engineering Laboratory, Idaho*, Masters Thesis, Department of Geology, Idaho State University, Pocatello, Idaho.

Hydraulic properties of surficial sediments at the Radioactive Waste Management Complex (RWMC), Idaho National Engineering Laboratory are required data for input to numerical models used to simulate the migration of radionuclides in the unsaturated zone. In situ estimates of hydraulic properties of surficial sediments adjacent to the RWMC were obtained from a field infiltration/drainage test. The study utilized a field plot, instrumented with tensiometers and two neutron probe access tubes, which was flooded for 24 hours, and then covered and allowed to drain. The unsaturated hydraulic properties were estimated by the instantaneous profile (K-θ) and the unit gradient (dK/dθ) methods and were analyzed using the FORTRAN code UNGRA. This program uses a non-linear, least -squares analysis to estimate the parameters of soil hydraulic properties, and fit analytical functions to observed retention and unsaturated hydraulic conductivity data. The soil water retention function was described using the equation of van Genuchten (1980), and the unsaturated hydraulic conductivity function was obtained by the combination of the van Genuchten retention function with the pore-size distribution model of Maulem (1976). Five different types of data sets were used in parameter estimation. These sets were: retention data alone, retention data with instantaneous profile K-θ data, K-θ alone, retention with unit gradient dK/dθ data, and unit gradient dK/dθ data alone. In the majority of cases, graphical results were similar between measured and predicted curves of both retention and hydraulic conductivity data, although hydraulic parameters estimated from curve-fitting showed little similarity. These plots also showed that unit gradient measurements can be substituted for the harder-to-obtain instantaneous profile measurements, and also provided results over a greater range of hydraulic conductivity values, even though tensiometer gradients were not always unity.

Laney, P. T., S. C. Minkin, R. G. Baca, D. L. McElroy, J. M. Hubbell, L. C. Hull, B. F. Russell, G. J. Stormberg, and J. T. Pittman, 1988, *Annual Progress Report: FY-1987, Subsurface Investigations Program at the Radioactive Waste Management Complex of the Idaho National Engineering Laboratory,* DOE/ID-10183, 153 pp.

The Subsurface Investigations Program made progress in FY-1987 toward obtaining its two program objectives: field calibration of a model to predict long-term radionuclide migration and measurement of the actual migration to date.

Three deep boreholes were drilled at the Radioactive Waste Management Complex (RWMC) to collect sample material for evaluation of radionuclide content in the interbeds, to determine geologic and hydrologic characteristics of the sediments, and to provide monitoring sites for moisture movement in these sediments. Suction lysimeters and heat dissipation sensors were installed in two deep boreholes to collect moisture data.

Data from the moisture sensing instruments (tensiometers, psychrometers, gypsum blocks, heat dissipation sensors, and neutron logging) installed at the RWMC continued to be collected during FY-1987. Because of the large volume of collected data, the RWMC Data Management System was developed and implemented to facilitate the storage, retrieval, and manipulation of the database.

Analysis of data from the soil-moisture sensing instruments was initiated. Hydraulic gradients indicated downward flow during large portions of the year, in several areas of the RWMC. Matric potential measurements within the SDA suggested the wettest soil-moisture conditions were near drainage and flood control ditches and topographic depressions. A need for statistical analysis of measurement results was identified, due to the variability of data at depths instrumented in triplicate.

Sampling of ambient air, air in boreholes, and soil gases was conducted at the RWMC to determine the identity, location, and relative concentrations of selected chlorinated and aromatic volatile organic compounds (VOCs). These sampling efforts indicated that carbon tetrachloride, 1,1,1-trichloroethane, trichloroethylene, and tetrachloroethylene have migrated from a number of the disposal pits where VOCs may have been disposed of. The major sources of VOCs appear to be Pits 4, 5, 6, 9, and 10. Measurable concentrations of VOCs occur in soil gases at distances from 2000 to 3400 ft from the SDA boundary. Analyses of gases collected at various depths beneath the RWMC indicate maximum gas concentrations at around 100 ft below land surface, and measurable concentrations to 576 ft.

Shallow auger hole samples from FY-1085 and FY-1986 were analyzed for radionuclides. Lysimeter water samples and sediment samples collected during FY-1986 and FY-1987 drilling were also analyzed for radionuclide parameters.

Results indicated several trends: slight downward migration of background radionuclides from the weathering of the surficial sediments, migration of radionuclides from the buried waste within the surficial sedimentary cover of the RWMC, and downward migration of radionuclides from the buried waste into the 110-ft interbed and possibly into the 240-ft interbed underlying the RWMC.

Notes:
1. Appendix A is the geologic description of deep drilling samples.
2. Appendix B is the geologic description of weighing lysimeter and test trench samples.
3. Appendix C is the results of soil gas sample analyses.
4. Appendix D is the structure for the database.
5. Appendix E is the tensiometer data.
6. Appendix F is the gypsum block data.
7. Appendix G is the heat dissipation sensor data.
8. Appendix H is the psychrometer data.

9. Appendix I is the neutron access probe data.
10. This is the third in a series of four annul progress reports on the Subsurface Investigations Program at the RWMC. See Hubbell, et al. 1985, Hubbell, et al. 1986, and McElroy, et al. 1989.

Magnuson, S. O., and D. L. McElroy, 1993, *Estimation of Infiltration from In Situ Moisture Contents and Representative Moisture Characteristic Curves for the 30', 110', and 240' Interbeds*, EDF RWM-93-001.1, EG&G Idaho, Inc.

Estimations of net infiltration into the vadose zone at the Radioactive Waste Management Complex were made based on data collected during the Subsurface Investigation Program (DOE, 1983). The data that was used consisted of in situ moisture contents measured on fifteen (15) samples retrieved during drilling from the 30', 110', and 240' interbeds. These samples were also hydrologically characterized for their moisture characteristic curves and saturated hydraulic conductivity. The in situ moisture contents and moisture characteristic curves for each sample are contained in McElroy and Hubbell (1990).

If equilibrium or steady-state conditions were prevalent at the time the samples were retrieved, the in situ moisture contents can be used in combination with the moisture characteristic curves to estimate the flux of water that was passing through the sample, since this downward flux of water is at depth it is an approximation of the net infiltration. The samples were analyzed individually and in grouped sets. Considerable judgment was required in selecting the groupings as well as in analyzing the resulting infiltration estimates. As part of this grouping process, estimations were made of representative or average moisture characteristic curves for each interbed.

In our judgment, the best infiltration estimate came from grouping the non-compacted samples from the 240' interbed. These samples resulted in infiltration estimates of 3.8 and 9.2 cm/yr. Since the samples were taken at depth, they represent an integration of all the transient water movement effects that occur above them in the geologic column. Analysis of individual samples resulted in infiltration estimates ranging from 0.014 to 55 cm/yr. Possible explanations for this wide range included effects of spatial variability in hydraulic properties, focusing of flow in fractures, transient water movement, and/or measurement errors.

Based on the analysis of data collected during the Subsurface Investigation Program, a reasonable range for infiltration inside the SDA appears to be from 4 to 10 cm/yr.

Notes:

1) The data used consisted of in situ moisture contents measured on 15 samples retrieved during drilling from the 30', 110', and 240' interbeds.
2) The samples were hydrologically characterized for their moisture characteristic curves and saturated hydraulic conductivity. See McElroy and Hubbell 1990 for the in situ moisture contents and moisture characteristic curves.
3) van Genuchten's (1980) moisture characteristic curve was used.

Martian, P. and S. O. Magnuson, 1994, *A Simulation Study of Infiltration Into Surficial Sediments at the Subsurface Disposal Area, Idaho National Engineering Laboratory*, EGG-WM-11250, EG&G Idaho, Inc.

Soil moisture monitoring data in the surficial sediments at the Subsurface Disposal Area (SDA) at the Idaho National Engineering Laboratory were used to calibrate two numerical infiltration models. The calibration was performed with the ultimate goal of providing a reliable estimate of hydraulic properties and infiltration amounts to be used in other modeling efforts. Two neutron probe access tubes and a tensiometer nest were monitored from 1986 to 1990 and again during 1993. The field measurements of moisture content and matric potential inside the SDA were used as calibration data for the two locations. The two locations showed vastly different behavior, which was well captured in the models. The average root mean square error between simulated and measured moisture contents over the simulation period was 0.03 and 0.06 for the two locations. The hydraulic parameters resulting from the calibration compared favorably with laboratory and field scale estimates.

The simulation results also provided the opportunity to partially explain infiltration and redistribution processes occurring at the SDA. The underlying fractured basalt appears to behave similar to a capillary barrier. This behavior inhibits moisture movement into the underlying basalts until moisture contents in the overlying silts approach saturation. As a result, a large proportion of recharge occurring at the SDA may be due to spring snowmelt, when the surficial sediments become nearly saturated. The results also indicated that a unit gradient boundary condition (free drainage due to gravity) at the bottom of the silts is not appropriate because of the very low relative hydraulic conductivity of the basalts. Finally, the amount of water moving into the SDA subsurface from spring snowmelt appears larger than cumulative snowfall, indicating that snow drifting due to local topography a well as current snow management practices may have a substantial influence on local infiltration.

McElroy, D. L., 1990, *Vadose Zone Monitoring at the Radioactive Waste Management Complex at the Idaho National Engineering Laboratory*, EGG-WM-9299, EG&G Idaho, Inc.

Appraisal of current disposal practices and delineation of contaminant plumes require accurate estimates of soil-water movement. Soil-water movement can be estimated from moisture-sensing instruments installed in the vadose zone. A network of vadose zone instruments was installed in surficial sediments and sedimentary interbeds beneath the Radioactive Waste Management Complex at the Idaho National Engineering Laboratory. Psychrometers, heat-dissipation sensors, gypsum blocks, tensiometers, and access holes for neutron logging were installed in a heterogeneous geologic system comprised of sediments that overlie and are intercalated with basalt flows. The instruments were monitored on a monthly basis since 1985. Matric potential in the surficial sediments (0 to 25 ft) generally ranged from saturation to 3 bars tension. Matric potentials in the 30-, 110-, and 240-ft interbeds were closely grouped within the range of 0 to 2.4 bars tension.

Sediments beneath surface depressions, drainage ditches, or areas flooded in the past were wetter than sediments located in more well-drained areas. The direction of moisture movement in the surficial sediments varied by borehole location. Boreholes showing predominantly upward gradients were located outside the Subsurface Disposal Area perimeter and away from disturbed areas. Infiltration was highly seasonal and occurred primarily during February to May when

evaporation rates were low. Snowmelt was a major source of water for infiltration. Limited data suggest a large percentage of the average yearly precipitation may recharge during this period. For the boreholes analyzed, maximum recharge occurred in a low spot near a ditch. However, recharge also occurred at a level, well-drained site. Based on matric potential patterns within the sediments, lithologic contacts may partially control moisture distribution in the surficial and sedimentary interbeds. Limited data suggest the possibility of downward moisture movement through the sedimentary interbeds.

Notes: The majority of the data is in the appendices.

1. Appendix A, The Table A-1 (1 page) caption says it shows the volumetric moisture content and corresponding neutron probe count for each sampled depth within Boreholes WO2 and WO6. It actually has the depth, moisture mass, bulk density, moisture volume, counts, average, and a regression of moisture content versus the counts.
2. Appendix B, has 75 pages of matric potential data and 26 pages of neutron probe counts that can be used to calculate the soil moisture content.
3. Appendix C has tables of matric potential and matric potential means for each depth.
4. Appendix D is precipitation and temperature data.
5. Appendix E - Table E-1 (1 page) are the calculations for change (increase) in moisture content (theta), Feb. 1989 to May 4, 1989. Table E-2 (1 page) are the calculations for change (decrease) in moisture content (theta), March 1989 to May 4, 1989.

McElroy, D. L., 1993, *Soil Moisture Monitoring Results at the Radioactive Waste Management Complex of the Idaho National Engineering Laboratory, FY-1993*, EGG-WM-11066, EG&G Idaho, Inc.

In FY-1993, two tasks were performed for the Radioactive Waste Management Complex (RWMC) Low Level Waste Performance Assessment to estimate net infiltration from rain and snow at the Subsurface Disposal Area (SDA) and provide soil moisture data for hydrologic model calibration. The first task was to calibrate the neutron probe to convert neutron count data to soil moisture contents. A calibration equation was developed and applied to four years of neutron probe monitoring data (November 1986 to November 1990) at WO2 and WO6 to provide soil moisture estimates for that period. The second task was to monitor the soils at two neutron probe access tubes (WO2 and WO6) located in the SDA of the RWMC with a neutron probe to estimate soil moisture contents. FY-1993 monitoring indicated net infiltration varied widely across the SDA. Less than 1.2 in. of water drained into the underlying basalts near WO2 in 1993. In contrast, an estimated 10.9 in. of water moved through the surficial sediments and into the underlying basalts at neutron probe access tube WO6. This network has since been expanded to address the variability in net infiltration across the SDA.

Notes: The data is contained in the appendices.

1. Appendix A - Procedure for installation of neutron access tubes for calibration of neutron probe description. Table A1 (1 page) gives the laboratory measurements and calculations for the dry bulk density. Table A2 (1 page) gives the neutron count and volumetric moisture content data used for linear regression.
2. Appendix B is a 58 page table of the volumetric moisture content as a function of time and depth for wells WO6 and WO2.
3. Appendix C has the field logbook entries pertinent to WO2 and WO6

monitoring, a geological description of drill samples, a geologic description from auger hole for neutron probe access tube WO2, and a geological description of the core samples.

4. Appendix D is a 13 page table of temperature and rainfall data.

5. Appendix E is a one page table of tensiometer data (manual measurements)from WO6.

McElroy, D. L. and J. M. Hubbell, 1990, *Hydrogeological and Physical Properties of Sediments from the Radioactive Waste Management Complex*, EGG-BG-9147, Idaho National Engineering Laboratory, EG&G Idaho, Inc.

Sediment samples from the Radioactive Waste Management Complex (RWMC) were analyzed for hydrological and physical properties pertinent to contaminant migration at the RWMC. Thirty-five samples were subcored from an archived collection of 19 core samples, which were collected from surficial (less than 30 ft below land surface) and interbed sediments (approximate depths of 110, 240, and 570 ft below land surface). These sediments overlie and are intercalated with fractured basalts at the RWMC. The sediments were analyzed for grain-size distribution, dry bulk density, porosity, particle density, moisture characteristics, saturated and unsaturated hydraulic conductivity, and air permeability.

Grain-size distributions and particle densities are representative of in-situ conditions for all of the samples. The long storage time of the samples, prior to analysis, yielded in-situ moisture contents which may be less than the in-situ field values. Some of the saturated hydraulic conductivities from these recent analyses were compared to previous hydraulic conductivities determined for the same samples. The results prior to storage and after two years of storage agreed within two orders of magnitude.

Sample compaction was evident in some samples analyzed for dry bulk density and moisture content-pressure head relationship. Variations in results for collocated samples reflect the vertical heterogeneity within the sediments and the need for a larger, more representative scale to be used for measurements.

Due to the long shelf-life and sample compaction, some of the dry bulk density, porosity, moisture characteristic, saturated and unsaturated hydraulic conductivity, and air permeability results have limited value and caution should be used in applying the data.

Notes:

1. The hydrologic properties laboratory results are presented in the appendices. Daniel B. Stephens & Associates, Inc. did the laboratory experiments.
2. The data is presented in the appendices as follows.
   - Appendix A-1 - Laboratory results for hydrologic properties, summary
   - Appendix A-2 - Initial Moisture content, dry bulk density, and porosity
   - Appendix A-3 - Particle-size distribution
   - Appendix A-4 - Particle density
   - Appendix A-5 - Moisture-retention characteristics
   - Appendix A-6 - Saturated hydraulic conductivity
   - Appendix A-7 - Unsaturated hydraulic conductivity
   - Appendix B - Laboratory results for air permeability

McElroy, D. L., S. A. Rawson, J. M. Hubbell, S. C. Minkin, R. G. Baca, M. J. Vigil, C. J. Bonzon, J. L. Landon, and P. T. Laney, 1989, *Annual Progress Report: FY-1988, Site Characterization Program at the Radioactive Waste Management Complex of the Idaho National Engineering Laboratory,* DOE/ID-10233.

The Radioactive Waste Management Complex (RWMC) Site Characterization Program is a continuation of the Subsurface Investigation Program (SIP). The scope of the SIP has broadened in response to the results of past work that identified hazardous as well as radionuclide contaminants in the subsurface environment and in response to the need to meet regulatory requirements.

Two deep boreholes were cored at the RWMC during FY-1988. Selected sediment samples were submitted for Appendix IX of 40 CFR Part 264 and radionuclide analyses. Detailed geologic logging of archived core was initiated. Stratigraphic studies of the unsaturated zone were conducted. Studies to determine hydrologic properties of sediments and basalts were conducted. Geochemical studies and analyses were initiated to evaluate contaminant and radionuclide speciation and migration in the Subsurface Disposal Area (SDA) geochemical environment.

Analyses of interbed sediments in boreholes D15 and 8801D did not confirm the presence of radionuclide contamination in the 240-ft interbed. Analyses of subsurface air and groundwater samples identified five volatile organic compounds of concern: carbon tetrachloride, trichloroethylene, 1,1,1-trichloroethane, chloroform, and tetrachloroethylene.

Data from vadose zone instrumentation suggested the occurrence of downward movement of soil water for large portions of the year. Preliminary solute transport modeling under unsaturated flow conditions is in general agreement with observed radionuclide migration and subsurface water contents. These modeling results suggest that fractures may play an important role in unsaturated flow and solute transport.

Notes:
1. This is the fourth in a series of four annul progress reports on the Subsurface Investigations Program at the RWMC. See Hubbell, et al. 1985, Hubbell, et al. 1986, and Laney, et al. 1988.

Rawson, S. A., J. C. Walton, and R. G. Baca, 1989, *Modeling Potential Migration of Petroleum Hydrocarbons from a Mixed-Waste Disposal Site in the Vadose Zone,* In: The Proceedings of the Petroleum Hydrocarbons and Organic Chemicals in Ground Water: Prevention, Detection and Restoration, A Conference and Exposition, Nov. 15-17, 1989, Houston Texas, Presented by the Association of Ground Water Scientists and Engineers, division of NWWA; and the American Petroleum Institute.

Environmental monitoring of a mixed-waste disposal site at the Idaho National Engineering Laboratory has confirmed release and migration into the vadose zone of: (1) chlorinated hydrocarbons in the vapor phase and (2) trace levels of certain transuranic elements. The findings has prompted an evaluation of the potential role of waste petroleum hydrocarbons in mediating or influencing contaminant migration from the disposal site. Disposal records indicate that a large volume of machine oil contaminated with transuranic isotopes was disposed at the site along with the chlorinated solvents and other radioactive wastes.

A multiphase flow model was used to assess the possible extent of oil and vapor movement through the 177 m thick vadose zone. One-dimensional simulations were performed to estimate the vertical distribution of the vapor phase, the aqueous phase, and immiscible free liquid as a function of time. The simulations indicate that the oil may migrate slowly through the vadose zone, to potentially significant depths. Calculated transport rates support the following ranking with regard to relative mobility: vapor phase > aqueous phase > free liquid.

Rawson, S. A., J. C. Walton, and R. G. Baca, 1991, Migration of Actinides from a Transuranic Waste Disposal Site in the Vadose Zone, Radiochimica Acta 52/53, 477-486.

Site characterization of a mixed-waste disposal site at the Idaho National Engineering Laboratory has confirmed release and migration into the vadose zone of chlorinated solvents and trace levels of $^{239+240}Pu$ and ^{241}Am within thirty-five years of disposal. A conceptual model of site geochemistry and its effects on actinide solubility and sorption was developed. Equilibrium geochemical codes were used to assess the chemical form of the actinides upon release from the site. Simulations of flow in a fractured medium were performed to estimate the distribution of the aqueous phase as a function of time. The simulations indicate that actinide migration in the aqueous phase to the observed depths is possible within a 10-30 year time frame.

Rightmire, C. T., 1984, *Description and Hydrogeologic Implications of Cored Sedimentary Material from the 1975 Drilling Program at the Radioactive Waste Management Complex, Idaho*, USGS Water-Resources Investigations Report 84-4071, June.

Samples of sedimentary material from interbeds between basalt flows and from fractures in the flows, taken from two drill cores at the Radioactive Waste Management Complex at the Idaho National Engineering Laboratory Were analyzed for 1) particle-size distribution, 2) bulk mineralogy, 3) clay mineralogy, 4) cation-exchange capacity, and 5) carbonate content. Thin sections of selected sedimentary material were made for petrographic examination. These analyses are needed for a characterization of paths and rates of movement of radionuclides transported by infiltrating water.

Preliminary interpretations indicate that 1) it may be possible to distinguish the various sedimentary interbeds on the basis of their mineralogy, 2) the presence of carbonate horizons in sedimentary interbeds may be utilized to approximate the time of exposure and the climate while the surface was exposed, and 3) the type and orientation of fracture-filling material may be utilized to determine the mechanism by which fractures were filled.

Notes:
1) this report is mostly grain size information.
2) page 20, - The particle-size data from both well 93A and well 96B show that fracture filling sediments are generally finer grained than interbed sediments. This is as expected. 0.5 mm was the coarsest particle seen in fracture-filling material in this section.
3) Table 3, particle-size distribution

4) Table 4, statistical grain-size analysis
5) Table 5, bulk mineralogy
6) tables 6 and 7, clay mineralogy, cation-exchange capacity, carbonate content

Rightmire, C. T. and B. D. Lewis, 1987b, *Hydrogeology and Geochemistry of the Unsaturated Zone, Radioactive Waste Management Complex, Idaho National Engineering Laboratory, Idaho*, USGS Open-File Report 87-246, DOE/ID-22073.

To assess the potential migration of low-level radioactive waste in the shallow subsurface, it is necessary to understand the chemical interactions that occur between solids, liquids, and gases in the unsaturated zone. For this purpose, a study on the geochemistry of the unsaturated zone at the Radioactive Waste Management Complex (RWMC), Idaho National Engineering Laboratory, on the eastern Snake River Plain in southeastern Idaho was done.

Stable isotope and chemical data suggest that the perched water observed beneath the RWMC is not due to vertical infiltration through the ground surface at the RWMC, but is due to lateral flow of water that infiltrated through the diversion ponds. It is hypothesized that the water accumulates as a perched mound on the thick, laterally continuous sedimentary interbed at a depth of 73 meters (m) and then moves about 1.5 kilometers to the northeast beneath the RWMC. Infiltrating water can move clay, silt, and sand downward through sedimentary material and open fractures, at least to the interbed at a depth of 73 m.

Oxygen isotope exchange and clay mineral alteration caused by extruded lave have been observed in the upper 0.86 m of the sedimentary interbed at a depth of 34 m and in the upper 2.65 m of the sedimentary interbed at a depth of 73 m. An examination of the sediment-basalt interrelation shows that the flows overlying the interbed at a depth of 73 m are substantially thicker than the flows overlying the interbed at a depth of 34 m (16 to 23 m compared to 6 to 10 m). Therefore, a greater influence of residual heat on the sedimentary unit that underlie the thicker flows, and thus greater alteration, may be expected. Sedimentary material at the RWMC shows isotopic and soils evidence of at least two major climatic changes within the last 200,000 years.

Notes:
1) this report does not have much information on the hydraulic parameters but a lot on grain size.
2) Table 2 shows the median grain size for surficial and interflow sedimentary units in wells at the RWMC.
3) Table 3 shows the particle size distribution for EWR subpit samples.

Shakofsky, S., 1993, *Changes in the Hydraulic Properties of a Soil Caused by Construction of a Waste Trench at a Radioactive Waste Disposal Site*, Masters Thesis, Department of Geology, San Jose State University, San Jose, California.

The changes in soil properties induced by the construction of a simulated waste burial trench were measured at a radioactive waste disposal site in the semi-arid southeast region of Idaho. Samples of an aridisol soil were collected, using a hydraulically-driven sampler to minimize sample disruption, from both a simulated waste trench and an undisturbed area nearby.

Results show an undisturbed profile with distinct horizons, whereas in the waste trench these layers are absent. Porosity was increased in the disturbed cores, and, correspondingly, saturated hydraulic conductivities were higher. Unsaturated hydraulic conductivities for the undisturbed cores were typically greater than the disturbed cores at higher water contents (greater than 0.32). At lower water contents a majority of the disturbed cores have greater hydraulic conductivities. In general the vertical movement of water is retarded in a layered medium, suggesting that the construction of the landfill has destroyed impediments to downward flow.

NOTES: Soil profiles in surficial sediments. She compares the following in disturbed and undisturbed sediments.

1. porosity (θ), saturated hydraulic conductivity (Ks), and bulk density (ρb)
2. θ vs Ψ at 5 depths
3. K vs θ at 5 depths
4. Some interesting figures comparing moisture content and K in disturbed and undisturbed soils.

3.0 HYDRAULIC CHARACTERISTIC DATA

This chapter is divided into the following four main sections;

Section 3.1 - Surficial Sediments Hydrogeologic Properties
Section 3.2 - Sedimentary Interbeds Hydrogeologic Properties
Section 3.3 - McElroy and Hubbell, 1990
Section 3.4 - Miscellaneous Information.

A Remedial Feasibility Investigation (RFI) was terminated when the RWMC was designated a CERCLA site. A fairly comprehensive report on the physical characteristics of the RWMC was almost complete at the time but was never published. The report summarized much of the work done at the RWMC before 1989. The tables and some of the text from the unpublished report are presented in Sections 3.1.1 (Summary of Data from EG&G Idaho, Inc. Studies - Surface Sediments) and 3.2.1 (Summary of Data from EG&G Idaho, Inc. Studies - Sedimentary Interbeds). These sections include literature reviews as well as the tables of data.

Tables and some text from McElroy and Hubbell, 1990 are included as Section 3.3 because the report covers both surface and interbed sediments. Some of the information is covered in Sections 3.1.1 and 3.2.1 but the complete tables are presented in Section 3.3 because this reference appears to be the most comprehensive and useful of all the references. Section 3.4 is a summary of some of the sediment parameter values used in past modeling studies.

3.1 Surficial Sediment Hydrogeologic Properties

This section summarizes the results of a number of studies that analyzed the surficial hydrogeologic properties. In addition to these studies, Jorgensen et al., 1994 Appendix B contains 32 pages of summary tables of the moisture content, density, porosity, saturated hydraulic conductivity and unsaturated hydraulic properties from the Acid Pit. These tables were not included in this report but may be useful to the modelers. Hertzler and Harris, 1989 summarized the statistical analyses of matric potential data collected from surficial sediment at the RWMC from May 1985 to September 1988. It is not clear how this information can be used; therefore, the tables are not included in this report.

3.1.1 Summary of Data from EG&G Idaho, Inc. Studies - Surface Sediments

The results of analyses of hydrogeologic properties of the surficial sediment were compiled from several sources. The studies from which the data were compiled are discussed briefly to provide information about the condition and analyses of the samples. The studies were generally limited to undisturbed areas of the SDA because of the safety problems inherent in sampling the waste pits.

Binda (1981) published particle-size distribution data collected from undisturbed areas along the SDA northern perimeter and central roadway. Information about the method of collection or analyses is not published.

Surficial sediment cores were collected by Barraclough et al. (1976) as part of a hydrogeologic investigation of the RWMC. The specific surficial sediment samples on which the analyses were performed were collected using rotary driven, Shelby-type split-spoon samplers. The retrieved samples were sealed at both ends with wax to prevent loss of moisture and physical disturbance. The cores were analyzed for particle-size distribution, saturated hydraulic conductivity, particle density, bulk density, porosity, and moisture content (gravimetric) at the USGS Laboratories in Denver, Colorado. The analytical procedures and results are described in Barraclough, et al. (1976).

Hubbell et al. (1985) and Hubbell et al. (1987) published the results of water content (gravimetric) analyses performed on surficial sediments collected from auguring of boreholes at the RWMC. The moisture-content samples were scraped from the drive shoe of the split-spoon and Shelby-tube samplers, stored in sealed aluminum containers, and analyzed within a week after collection. Moisture contents were determined by net change of weight after drying the soil to a constant weight in an oven at 105°C.

Rightmire and Lewis (1987) performed a geochemical investigation of the unsaturated zone at the RWMC. As part of their investigation, particle-size distributions were analyzed for selected cores by the USGS Hydrologic Laboratory. The analyzed samples (EWR1-1 through EWR1-4) were collected from undisturbed soil beneath Pit 2 (Humphrey and Tingey, 1978). The sediment was exposed by a backhoe, and drive tubes were pressed horizontally into the exposed sediment wall. The samples were bagged and sealed upon retrieval.

McElroy and Hubbell (1990) (see Section 3.3) presents hydrogeologic data that include the properties listed for Barraclough et al. (1976) with the addition of moisture-release curves, unsaturated hydraulic conductivity, and air permeability. These samples were collected from auger holes by driving a Shelby tube and sealing the samples before storage. Wherever possible, analyses were performed using standard ASTM procedures described in McElroy and Hubbell (1990). The samples were stored for up to three years before analysis. The storage period probably affected the saturated and unsaturated hydraulic conductivity, moisture-release curve, moisture content, porosity, and air permeability results. However, these data are valuable because of the derth of similar data from undisturbed cores.

The results of analyses of hydrogeologic data from the above mentioned studies are presented in Tables 3.1.1-1, 3.1.1-2, 3.1.1-3, (and Appendix A of McElroy and Hubbell, 1990). Table 3.1.1-1 lists particle-size distribution data. Particle density, bulk density, porosity, moisture content, and saturated vertical hydraulic conductivity are presented in Table 3.1.1-2. Table 3.1.1-3 lists the air permeability data for both the dry condition and the in situ (native state) condition. Moisture-release curves and unsaturated hydraulic conductivities (as a function of water content and pressure head) are presented in Appendix A of McElroy and Hubbell (1990).

Table 3.1.1-1. Particle size distributions, for surficial sediments, presented as percent weight in each size category.

		Particle-size Distribution														Statistical Parameters					
		Depth Interval		%Clay (mm)	%Silt (mm)	% Sand (mm)							% Gravel (mm)								
Sample Number	Well Number	Top (ft)	bottom (ft)	<0.004	0.004-0.062	.062-.125	.125-.250	.250-.500	.500-1.00	1.00-2.00	2.00-4.00	4.00-8.00	8.00-16.0	16.0-32.0	32.0-64.0	Median	Sorting Coefficient	Coefficient of Skewness	Kurtosis	Coefficient of Uniformity	Reference[a]
	BG-92	2.6	5.0	21.2	48.8	22.4	6.7	.6	.4	0	0	0	0	0	0	2.2×10^{-2}	3.5	.88	-	-	1
	BG-93	12.1	14.0	49.1	45.1	4.2	1.2	.2	.2	0	0	0	0	0	0	3.6×10^{-3}	1.6	13.	-	-	1
	BG-94	6.5	8.3	38.7	56.5	3.2	1.6	.0	.0	0	0	0	0	0	0	8.0×10^{-2}	1.2	6.6	-	-	1
	BG-94	8.3	8.7	38.2	50.9	9.1	1.8	.0	.0	0	0	0	0	0	0	4.4×10^{-3}	-	-	-	-	1
	BG-95	10.0	12.5	38.5	55.6	3.6	2.3	.0	.0	0	0	0	0	0	0	8.0×10^{-3}	5.0	.33	-	-	1
	BG-95	17.5	20.0	9.9	73.0	8.6	6.4	1.8	.2	.2	0	0	0	0	0	3.5×10^{-2}	2.0	.59	0.19	11	1
	BG-96	12.8	15.0	33.6	57.7	57.7	7.1	1.6	.0	0	0	0	0	0	0	1.1×10^{-2}	4.6	.31	-	-	1
ST09	W06	1.7	2.7	16.57	28.9	31.09	14.57	0.3	0.02	0	0	0	0	-	-	0.075	-	-	-	61.5	2
ST20	W09	6.0	7.0	8.38	22.3	12.43	29.39	23.39	0.02	0.01	0	0	0	-	-	0.12	-	-	-	2.8	2
ST06	W24	7.4	8.3	24.28	16.9	22.46	30.91	0.42	0.25	0	0	0	0	-	-	0.079	-	-	-	-	2
ST10	W06	11.0	11.8	5.58	19.3	22.24	42.78	1.64	0.07	0	0.04	0	1.05	-	-	0.12	-	-	-	10.	2
EWR-1-4	PIT2	3.0		53.3	38.5	4.8	2.3	.9	.1												3
EWR-1-3	PIT2	4.0		41.0	30.1	11.0	17.7	.2	0												3
EWR-1-2	PIT2	5.0		54.7	40.1	4.1	0.7	.2	.1												3
EWR-1-1	PIT2	6.0		23.5	69.8	6.	0.6	0	.1												3

		Depth Interval	%Clay (mm)	%Silt (mm)	% Sand (mm)						% Gravel (mm)									
			0.001-0.005	0.074-0.005	.075-.150	.150-.175	.175-.25	.25-.30	.30-.425	.425-2.0	2.0-4.75	>4.75								
1-1	1	2.0	29.1	33.4	13.2	3.4	9.2	4.2	4.4	3.1	0	0	-	-	-	-	-	-	-	4
1-2	1	5.0	16.0	55.4	23.7	2.	2.2	.2	.2	.3	0	0	-	-	-	-	-	-	-	4
1-3	1	7.0	19.1	50.0	8.4	6.6	8.8	1.5	1.	2.3	2.3	0	-	-	-	-	-	-	-	4
2-1	2	10.0	33.6	46.4	8.3	2.3	4.9	1.8	1.6	1.2	0	0	-	-	-	-	-	-	-	4
2-2	2	3.0	14.9	51.1	12.9	1.5	1.5	.3	.5	4.1	13.2	0	-	-	-	-	-	-	-	4
2-3	2	6.0	36.8	46.1	6.6	.8	.9	.3	.5	2.5	5.4	0	-	-	-	-	-	-	-	4
3-1	3	10.0	36.7	51.9	6.6	.5	.6	.2	.2	.1	.3	0	-	-	-	-	-	-	-	4
4-1	4	1.5	9.6	15.4	26.6	9.3	18.8	7.6	8.8	3.9	0	0	-	-	-	-	-	-	-	4
4-2	4	4.0	19.7	68.4	6.2	.9	1.8	.8	.8	1.4	0	0	-	-	-	-	-	-	-	4
4-3	4	6.0	5.9	34.5	24.2	8.9	15.6	5.	3.7	2.2	0	0	-	-	-	-	-	-	-	4
5-1	5	2.0	31.5	31.6	12.6	5.3	11.6	3.3	2.4	1.7	0	0	-	-	-	-	-	-	-	4
5-2	5	5.0	33.5	53.2	7.3	1.	1.9	.8	.8	1.5	0	0	-	-	-	-	-	-	-	4
5-3	5	7.5	26.5	60.7	-	-	.9	.4	.4	4.3	.9	0	-	-	-	-	-	-	-	4
5-4	5	10.0	27.3	62.5	5.2	.3	.7	.4	.6	1.	1.6	0	-	-	-	-	-	-	-	4
5-5	5	13.0	35.1	59.5	.3	.2	.2	.2	.0	.7	.8	0	-	-	-	-	-	-	-	4
5-6	5	15.0	31.1	62.0	3.5	.2	.2	.2	.0	2.8	0	0	-	-	-	-	-	-	-	4
5A-1	5A	3.0	19.8	70.1	7.7	.6	.6	.4	.0	.9	0	0	-	-	-	-	-	-	-	4
5A-2	5A	6.0	15.8	68.3	11.	1.4	1.8	.4	.2	1.1	0	0	-	-	-	-	-	-	-	4
5A-3	5A	9.0	27.9	66.6	4.4	.2	.4	.2	.0	.3	0	0	-	-	-	-	-	-	-	4

Table 3.1.1-1. (continued)

		Depth Interval		Particle-size Distribution												Statistical Parameters					
				%Clay (mm)	%Silt (mm)	% Sand (mm)						% Gravel (mm)									
Sample Number	Well Number	Top (ft)	bottom (ft)	0.001-0.005	0.074-0.005	.075-.150	.150-.175	.175-.25	.25-.30	.30-.425	.425-2.0	2.0-4.75	>4.75	16.0-32.0	32.0-64.0	Median	Sorting Coefficient	Coefficient of Skewness	Kurtosis	Coefficient of Uniformity	Reference[a]
6-1	6	3.0		46.0	29.8	2.4	.3	.4	.2	.2	.6	21.1	0	-	-	-	-	-	-	-	4
7-1	7	3.0		15.6	74.0	6.4	.4	.6	.2	.2	1.3	1.3	0	-	-	-	-	-	-	-	4
7-2	7	6.0		31.2	58.2	7.	.4	.6	.2	.0	.2	2.2	0	-	-	-	-	-	-	-	4
7-3	7	9.0		16.0	76.4	6.8	.2	.4	.2	0	0	0	0	-	-	-	-	-	-	-	4
8-1	8	3.0		45.2	48.3	3.3	.4	.6	.4	.0	1.8	0	0	-	-	-	-	-	-	-	4
8-2	8	6.0		47.4	48.5	.2	.2	.2	.2	.2	1.3	0	0	-	-	-	-	-	-	-	4
8-3	8	9.0		39.3	54.8	3.1	.2	.4	.2	.2	1.8	0	0	-	-	-	-	-	-	-	4
9-1	9	3.0		21.9	64.3	10.9	.8	1.2	.2	.2	.5	0	0	-	-	-	-	-	-	-	4
10-1	10	3.0		27.2	60.6	6.6	.6	1.2	.3	.6	2.9	0	0	-	-	-	-	-	-	-	4
10-2	10	6.0		52.9	39.1	4.3	.4	.6	.6	.0	2.1	0	0	-	-	-	-	-	-	-	4
10-3	10	9.0		37.8	55.4	5.6	.2	.4	.0	.0	.6	0	0	-	-	-	-	-	-	-	4
11-1	11	3.0		13.4	56.1	19.1	3.1	2.7	.5	.6	1.8	2.7	0	-	-	-	-	-	-	-	4
12-1	12	3.0		31.0	50.5	11.	.4	1.7	.6	.8	2.1	.9	0	-	-	-	-	-	-	-	4
13-2	13	6.0		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
13-3	13	9.0		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
14-1	14	3.0		8.4	46.2	9.6	1.5	4.5	4.1	9.9	13.4	2.4	0	-	-	-	-	-	-	-	4
14-3	14	10.0		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
15-1	15	3.0		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
16-1	16	4.0		11.8	58.3	11.7	1.2	.9	.1	15.	1.	0	0	-	-	-	-	-	-	-	4
16-2	16	8.0		45.1	46.7	4.9	.4	.6	.2	.2	1.9	0	0	-	-	-	-	-	-	-	4
16-3	16	13.0		43.2	43.8	6.3	.8	1.9	1.4	.8	1.8	0	0	-	-	-	-	-	-	-	4
17-1	17	3.0		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
17-2	17	6.0		8.3	33.9	19.9	7.0	17.7	2.6	2.6	5.6	2.4	0	-	-	-	-	-	-	-	4
17-3	17	9.0		38.9	50.4	4.5	.8	1.5	.6	.8	2.7	0	0	-	-	-	-	-	-	-	4
18-1	18	3.0		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
18-2	18	6.0		55.6	40.9	1.4	.2	.2	.2	.0	.8	.7	0	-	-	-	-	-	-	-	4

References:

a. 1. Barraclough et al. (1976)
   2. McElroy and Hubbell (1990)
   3. Rightmire and Lewis (1987)
   4. Binda (1981)

Table 3.1.1-2. Hydrogeologic properties from surficial sediment samples.

Sample Number	Borehole Number	Depth Interval Top (ft)	Depth Interval Bottom (ft)	Particle Density (g/cc)	Bulk Density (g/cc)	Porosity %	Moisture Content (%, g/g)	Saturated Moisture Content (%, g/cc)	Vertical Hydraulic Conductivity (cm/s)	Reference[a]
	BG-92	2.6	5.0	2.65	1.87	34.3	12.9	-	6.37×10^{-7}	1
	BG-93	12.1	14.0	2.64	1.81	41.6	27.3	-	3.01×10^{-7}	1
	BG-94	6.5	8.3	2.67	2.02	30.5	16.4	-	3.13×10^{-7}	1
	BG-94	8.3	8.7	2.67	-	21.0	-	-	1.11×10^{-8}	1
	BG-95	10.0	12.5	2.66	1.70	41.0	13.2	-	9.14×10^{-6}	1
	BG-95	17.5	20.0	2.65	1.53	43.4	3.15	-	6.25×10^{-4}	1
	BG-96	12.8	15.0	2.66	1.94	37.6	27.7	-	6.94×10^{-4}	1
ST09	W06	1.7	2.7	2.57	1.33	48.1	-	51.1	1.71×10^{-4}	2
ST20	W09	6.0	7.0	2.62	1.35	48.3	25.1	47.9	7.17×10^{-5}	2
ST06	W24	7.4	8.3	2.62	1.35	48.3	20.5	45.1	4.54×10^{-5}	2
ST10	W06	11.0	11.8	2.62	1.42	45.6	28.7	49.6	5.96×10^{-5}	2
1-1	1	2.0	-	2.56	-	-	7.0	-	-	3
1-2	1	5.0	-	2.63	-	-	9.9	-	-	3
1-3	1	7.0	-	2.62	-	-	6.5	-	-	3
2-1	2	2.0	-	2.60	-	-	2.0	-	-	3
2-2	2	2.0	-	2.61	-	-	6.1	-	-	3
2-3	2	2.0	-	2.61	-	-	13.9	-	-	3
3-1	3	3.0	-	2.64	-	-	9.8	-	-	3
4-1	4	4.0	-	2.66	-	-	4.7	-	-	3
4-2	4	4.0	-	2.65	-	-	11.7	-	-	3
4-3	4	4.0	-	2.67	-	-	9.1	-	-	3
5-1	5	5.0	-	2.62	-	-	11.4	-	-	3
5-2	5	5.0	-	2.60	-	-	11.4	-	-	3
5-3	5	5.0	-	2.58	-	-	15.9	-	-	3
5-4	5	5.0	-	2.58	-	-	13.2	-	-	3
5-5	5	5.0	-	2.64	-	-	15.4	-	-	3
5-6	5	5.0	-	2.65	-	-	15.6	-	-	3
5A-1	5A	3.0	-	2.58	-	-	9.0	-	-	3
5A-2	5A	6.0	-	2.62	-	-	11.8	-	-	3
5A-3	5A	9.0	-	2.58	-	-	10.6	-	-	3
6-1	6	6.0	-	2.53	-	-	15.4	-	-	3
7-1	7	7.0	-	2.61	-	-	13.4	-	-	3
7-2	7	7.0	-	2.59	-	-	14.2	-	-	3
7-3	7	7.0	-	2.66	-	-	14.8	-	-	3
8-1	8	8.0	-	2.58	-	-	11.9	-	-	3
8-2	8	8.0	-	2.61	-	-	14.0	-	-	3
8-3	8	8.0	-	2.59	-	-	15.3	-	-	3
9-1	9	9.0	-	2.59	-	-	12.5	-	-	3
10-1	10	10.0	-	2.58	-	-	11.7	-	-	3
10-2	10	10.0	-	2.48	-	-	18.8	-	-	3

Table 3.1.1-2. (continued 2/8)

Sample Number	Borehole Number	Depth Interval Top (ft)	Bottom (ft)	Particle Density (g/cc)	Bulk Density (g/cc)	Porosity %	Moisture Content (%, g/g)	Saturated Moisture Content (%, g/cc)	Vertical Hydraulic Conductivity (cm/s)	Reference[a]
10-3	10	10.0	-	2.55	-	-	17.0	-	-	3
11-1	11	11.0	-	2.58	-	-	9.2	-	-	3
12-1	12	12.0	-	2.50	-	-	13.9	-	-	3
13-2	13	13.0	-	-	-	-	2.9	-	-	3
13-3	13	13.0	-	-	-	-	6.9	-	-	3
14-1	14	14.0	-	2.64	-	-	10.1	-	-	3
14-3	14	14.0	-	-	-	-	3.6	-	-	3
15-1	15	15.0	-	-	-	-	2.4	-	-	3
16-1	16	16.0	-	2.61	-	-	8.4	-	-	3
16-2	16	16.0	-	2.53	-	-	16.1	-	-	3
16-3	16	16.0	-	2.64	-	-	20.9	-	-	3
17-1	17	17.0	-	-	-	-	3.1	-	-	3
17-2	17	17.0	-	2.68	-	-	12.0	-	-	3
17-3	17	17.0	-	2.54	-	-	19.3	-	-	3
18-1	18	18.0	-	-	-	-	5.3	-	-	3
18-2	18	18.0	-	2.44	-	-	20.1	-	-	3
	C02	2.26	-	-	-	-	16.	-	-	4
	C02	4.00	-	-	-	-	15.3	-	-	4
	C02	5.41	-	-	-	-	20.8	-	-	4
	PA01	2.33	-	-	-	-	24.5	-	-	4
	PA01	4.07	-	-	-	-	28.5	-	-	4
	PA01	5.84	-	-	-	-	3.1	-	-	4
	PA01	7.58	-	-	-	-	20.0	-	-	4
	PA01	9.32	-	-	-	-	21.1	-	-	4
	PA01	11.09	-	-	-	-	18.5	-	-	4
	PA01	12.82	-	-	-	-	22.8	-	-	4
	PA01	14.66	-	-	-	-	16.6	-	-	4
	PA02	2.59	-	-	-	-	16.9	-	-	4
	PA02	5.35	-	-	-	-	29.3	-	-	4
	PA02	7.08	-	-	-	-	13.7	-	-	4
	PA02	8.82	-	-	-	-	6.6	-	-	4
	T12	2.49	-	-	-	-	7.7	-	-	4
	T12	4.26	-	-	-	-	10.9	-	-	4
	T12	4.99	-	-	-	-	11.5	-	-	4
	T23	2.43	-	-	-	-	15.	-	-	4
	T23	4.17	-	-	-	-	21.2	-	-	4
	T23	5.90	-	-	-	-	11.4	-	-	4
	T23	7.68	-	-	-	-	9.1	-	-	4
	T23	8.59	-	-	-	-	3.0	-	-	4
	T23	10.33	-	-	-	-	5.4	-	-	4

Table 3.1.1-2. (continued 3/8).

Sample Number	Borehole Number	Depth Interval Top (ft)	Bottom (ft)	Particle Density (g/cc)	Bulk Density (g/cc)	Porosity %	Moisture Content (%, g/g)	Saturated Moisture Content (%, g/cc)	Vertical Hydraulic Conductivity (cm/s)	Reference[a]
	T23	12.07	-	-	-	-	20.2	-	-	4
	T23	13.84	-	-	-	-	20.7	-	-	4
	T23	15.58	-	-	-	-	18.0	-	-	4
	T23	17.32	-	-	-	-	21.8	-	-	4
	T23	19.32	-	-	-	-	28.3	-	-	4
	T23	19.91	-	-	-	-	26.3	-	-	4
	TH01	2.43	-	-	-	-	16.9	-	-	4
	TH01	4.17	-	-	-	-	20.0	-	-	4
	TH01	5.90	-	-	-	-	24.7	-	-	4
	TH02	2.43	-	-	-	-	14.0	-	-	4
	TH02	4.17	-	-	-	-	26.5	-	-	4
	TH02	5.90	-	-	-	-	27.6	-	-	4
	TH03	2.43	-	-	-	-	16.6	-	-	4
	TH03	4.17	-	-	-	-	18.9	-	-	4
	TH03	4.99	-	-	-	-	13.2	-	-	4
	TH04	0.00	-	-	-	-	19.7	-	-	4
	TH04	1.97	-	-	-	-	23.9	-	-	4
	TH04	4.00	-	-	-	-	21.0	-	-	4
	TH04	6.00	-	-	-	-	26.9	-	-	4
	TH04	7.97	-	-	-	-	22.0	-	-	4
	TH04	11.15	-	-	-	-	19.6	-	-	4
	W01	2.49	-	-	-	-	13.0	-	-	4
	W01	4.26	-	-	-	-	18.9	-	-	4
	W01	6.00	-	-	-	-	16.3	-	-	4
	W01	7.74	-	-	-	-	17.5	-	-	4
	W02	2.49	-	-	-	-	12.7	-	-	4
	W02	4.26	-	-	-	-	11.0	-	-	4
	W02	6.00	-	-	-	-	8.9	-	-	4
	W02	7.74	-	-	-	-	28.5	-	-	4
	W02	9.51	-	-	-	-	21.2	-	-	4
	W02	11.25	-	-	-	-	20.1	-	-	4
	W02	12.99	-	-	-	-	25.5	-	-	4
	W02	14.66	-	-	-	-	26.4	-	-	4
	W03	2.49	-	-	-	-	11.6	-	-	4
	W03	4.26	-	-	-	-	14.2	-	-	4
	W03	5.67	-	-	-	-	15.7	-	-	4
	W03	7.41	-	-	-	-	13.4	-	-	4
	W03	9.15	-	-	-	-	12.8	-	-	4
	W03	10.92	-	-	-	-	8.3	-	-	4
	W04	2.49	-	-	-	-	8.6	-	-	4

Table 3.1.1-2. (continued 4/8).

Sample Number	Borehole Number	Depth Interval Top (ft)	Bottom (ft)	Particle Density (g/cc)	Bulk Density (g/cc)	Porosity %	Moisture Content (%, g/g)	Saturated Moisture Content (%, g/cc)	Vertical Hydraulic Conductivity (cm/s)	Reference[a]
	W04	4.26	-	-	-	-	17.0	-	-	4
	W04	6.00	-	-	-	-	19.9	-	-	4
	W04	7.74	-	-	-	-	22.1	-	-	4
	W04	9.51	-	-	-	-	24.6	-	-	4
	W04	11.25	-	-	-	-	25.5	-	-	4
	W04	13.32	-	-	-	-	22.6	-	-	4
	W04	15.15	-	-	-	-	27.5	-	-	4
	W04	16.92	-	-	-	-	24.6	-	-	4
	W04	18.66	-	-	-	-	15.7	-	-	4
	W04	20.57	-	-	-	-	20.4	-	-	4
	W04	22.34	-	-	-	-	22.4	-	-	4
	W04	24.08	-	-	-	-	17.2	-	-	4
	W04	24.90	-	-	-	-	13.9	-	-	4
	W08	2.33	-	-	-	-	17.9	-	-	4
	W08	4.07	-	-	-	-	7.1	-	-	4
	W08	5.84	-	-	-	-	19.0	-	-	4
	W08	7.58	-	-	-	-	10.8	-	-	4
	W08	9.32	-	-	-	-	9.9	-	-	4
	W08	10.92	-	-	-	-	13.1	-	-	4
	W08	12.66	-	-	-	-	20.9	-	-	4
	W08	14.40	-	-	-	-	17.5	-	-	4
	W08	16.17	-	-	-	-	18.8	-	-	4
	W08	17.91	-	-	-	-	17.8	-	-	4
	W08	20.07	-	-	-	-	18.2	-	-	4
	W08	21.81	-	-	-	-	19.8	-	-	4
	W08	22.24	-	-	-	-	21.5	-	-	4
	W10	2.43	-	-	-	-	11.5	-	-	4
	W10	4.17	-	-	-	-	16.9	-	-	4
	W10	5.90	-	-	-	-	23.1	-	-	4
	W10	7.68	-	-	-	-	16.4	-	-	4
	W10	9.41	-	-	-	-	14.9	-	-	4
	W10	10.33	-	-	-	-	14.3	-	-	4
	W12	2.43	-	-	-	-	6.0	-	-	4
	W12	4.17	-	-	-	-	19.2	-	-	4
	W16	2.33	-	-	-	-	12.0	-	-	4
	W16	4.07	-	-	-	-	25.2	-	-	4
	W16	4.99	-	-	-	-	17.5	-	-	4
	W19	2.33	-	-	-	-	15.1	-	-	4
	W19	4.07	-	-	-	-	3.4	-	-	4
	W19	5.84	-	-	-	-	18.4	-	-	4

Table 3.1.1-2. (continued 5/8).

Sample Number	Borehole Number	Depth Interval Top (ft)	Bottom (ft)	Particle Density (g/cc)	Bulk Density (g/cc)	Porosity %	Moisture Content (%, g/g)	Saturated Moisture Content (%, g/cc)	Vertical Hydraulic Conductivity (cm/s)	Reference[a]
	W19	40.38	-	-	-	-	17.7	-	-	4
	W19	9.32	-	-	-	-	16.4	-	-	4
	W19	11.09	-	-	-	-	17.7	-	-	4
	W19	12.82	-	-	-	-	19.0	-	-	4
	W19	14.60	-	-	-	-	15.5	-	-	4
	W19	16.33	-	-	-	-	18.0	-	-	4
	W19	16.76	-	-	-	-	13.2	-	-	4
	W20	2.43	-	-	-	-	17.7	-	-	4
	W20	4.17	-	-	-	-	14.2	-	-	4
	W20	5.90	-	-	-	-	11.5	-	-	4
	W20	7.68	-	-	-	-	19.0	-	-	4
	W22	2.43	-	-	-	-	15.0	-	-	4
	W22	4.17	-	-	-	-	17.1	-	-	4
	W22	5.90	-	-	-	-	19.4	-	-	4
	W22	7.68	-	-	-	-	14.3	-	-	4
	W22	8.92	-	-	-	-	19.5	-	-	4
	W23	2.33	-	-	-	-	10.9	-	-	4
	W23	4.07	-	-	-	-	19.9	-	-	4
	W23	5.84	-	-	-	-	11.7	-	-	4
	W23	7.58	-	-	-	-	7.7	-	-	4
	W23	9.32	-	-	-	-	2.2	-	-	4
	W23	11.09	-	-	-	-	3.3	-	-	4
	W23	12.82	-	-	-	-	24.9	-	-	4
	W23	14.60	-	-	-	-	23.9	-	-	4
	W23	16.33	-	-	-	-	21.6	-	-	4
	W23	18.07	-	-	-	-	18.3	-	-	4
	W23	19.84	-	-	-	-	36.3	-	-	4
224	W05	1.7	-	-	-	-	9.0	-	-	5
225	W05	3.3	-	-	-	-	19.0	-	-	5
226	W05	5.0	-	-	-	-	14.9	-	-	5
227	W05	7.7	-	-	-	-	26.3	-	-	5
228	W05	9.3	-	-	-	-	23.5	-	-	5
229	W05	11.0	-	-	-	-	27.6	-	-	5
230	W05	12.7	-	-	-	-	18.9	-	-	5
231	W05	14.3	-	-	-	-	23.2	-	-	5
232	W05	16.0	-	-	-	-	45.4	-	-	5
233	W06	1.7	-	-	-	-	9.5	-	-	5
234	W06	4.3	-	-	-	-	15.8	-	-	5
234	W06	6.0	-	-	-	-	16.7	-	-	5
236	W06	7.7	-	-	-	-	19.0	-	-	5

Table 3.1.1-2. (continued 6/8)

Sample Number	Borehole Number	Depth Interval Top (ft)	Depth Interval Bottom (ft)	Particle Density (g/cc)	Bulk Density (g/cc)	Porosity %	Moisture Content (%, g/g)	Saturated Moisture Content (%, g/cc)	Vertical Hydraulic Conductivity (cm/s)	Reference[a]
237	W06	9.3	-	-	-	-	22.6	-	-	5
238	W06	11.0	-	-	-	-	27.4	-	-	5
284	W09	1.7	-	-	-	-	8.2	-	-	5
285	W09	4.3	-	-	-	-	21.9	-	-	5
286	W09	6.0	-	-	-	-	15.8	-	-	5
287	W09	8.7	-	-	-	-	5.0	-	-	5
288	W09	10.3	-	-	-	-	7.0	-	-	5
289	W09	12.0	-	-	-	-	21.4	-	-	5
290	W09	13.7	-	-	-	-	22.8	-	-	5
291	W09	14.8	-	-	-	-	16.7	-	-	5
200	W11	2.3	-	-	-	-	9.4	-	-	5
201	W11	4.0	-	-	-	-	14.9	-	-	5
202	W11	5.7	-	-	-	-	15.4	-	-	5
203	W11	7.3	-	-	-	-	14.2	-	-	5
204	W11	10.0	-	-	-	-	15.5	-	-	5
205	W11	11.7	-	-	-	-	14.7	-	-	5
206	W11	13.3	-	-	-	-	16.2	-	-	5
207	W11	15.0	-	-	-	-	21.1	-	-	5
208	W11	16.5	-	-	-	-	10.8	-	-	5
258	W13	1.7	-	-	-	-	12.2	-	-	5
259	W13	3.3	-	-	-	-	10.7	-	-	5
260	W13	5.0	-	-	-	-	12.9	-	-	5
261	W13	7.7	-	-	-	-	22.7	-	-	5
262	W13	9.3	-	-	-	-	21.5	-	-	5
263	W13	11.0	-	-	-	-	7.3	-	-	5
264	W13	12.7	-	-	-	-	3.3	-	-	5
265	W13	14.3	-	-	-	-	22.3	-	-	5
266	W13	16.0	-	-	-	-	23.8	-	-	5
267	W13	17.7	-	-	-	-	24.6	-	-	5
272	W17	1.7	-	-	-	-	19.1	-	-	5
273	W17	3.3	-	-	-	-	17.5	-	-	5
274	W17	5.0	-	-	-	-	15.3	-	-	5
275	W17	6.7	-	-	-	-	13.8	-	-	5
276	W17	9.3	-	-	-	-	14.3	-	-	5
277	W17	11.0	-	-	-	-	12.9	-	-	5
278	W17	12.7	-	-	-	-	13.7	-	-	5
279	W17	14.3	-	-	-	-	15.3	-	-	5
280	W17	16.0	-	-	-	-	13.1	-	-	5
281	W17	17.7	-	-	-	-	18.3	-	-	5
282	W17	19.3	-	-	-	-	10.9	-	-	5

Table 3.1.1-2. (continued 7/8)

Sample Number	Borehole Number	Depth Interval Top (ft)	Bottom (ft)	Particle Density (g/cc)	Bulk Density (g/cc)	Porosity %	Moisture Content (%, g/g)	Saturated Moisture Content (%, g/cc)	Vertical Hydraulic Conductivity (cm/s)	Reference[a]
283	W17	20.4	-	-	-	-	15.2	-	-	5
248	W18	1.7	-	-	-	-	11.4	-	-	5
249	W18	4.3	-	-	-	-	19.9	-	-	5
250	W18	6.0	-	-	-	-	15.5	-	-	5
251	W18	7.7	-	-	-	-	15.4	-	-	5
252	W18	9.3	-	-	-	-	13.0	-	-	5
253	W18	10.8	-	-	-	-	10.9	-	-	5
254	W18	12.5	-	-	-	-	11.2	-	-	5
255	W18	14.2	-	-	-	-	10.0	-	-	5
256	W18	15.8	-	-	-	-	13.6	-	-	5
257	W18	16.4	-	-	-	-	7.8	-	-	5
209	W24	2.4	-	-	-	-	18.8	-	-	5
210	W24	4.1	-	-	-	-	13.8	-	-	5
211	W24	5.8	-	-	-	-	15.9	-	-	5
212	W24	7.4	-	-	-	-	18.9	-	-	5
ST6	W24	8.3	-	-	-	-	22.6	-	-	5
239	W25	1.7	-	-	-	-	23.9	-	-	5
240	W25	3.3	-	-	-	-	10.7	-	-	5
241	W25	5.0	-	-	-	-	12.6	-	-	5
242	W25	6.7	-	-	-	-	12.1	-	-	5
243	W25	8.3	-	-	-	-	14.5	-	-	5
244	W25	11.0	-	-	-	-	3.1	-	-	5
245	W25	12.7	-	-	-	-	18.2	-	-	5
246	W25	14.3	-	-	-	-	21.2	-	-	5
247	W25	15.5	-	-	-	-	25.8	-	-	5
214	C01	1.7	-	-	-	-	3.9	-	-	5
215	C01	3.3	-	-	-	-	8.0	-	-	5
216	C01	5.0	-	-	-	-	6.0	-	-	5
217	C01	6.7	-	-	-	-	3.6	-	-	5
218	C01	9.3	-	-	-	-	23.2	-	-	5
219	C01	11.0	-	-	-	-	20.5	-	-	5
220	C01	12.7	-	-	-	-	20.9	-	-	5
221	C01	14.3	-	-	-	-	19.4	-	-	5
222	C01	16.0	-	-	-	-	21.6	-	-	5
223	C01	17.7	-	-	-	-	17.5	-	-	5
T1	TH05	3.2	-	-	-	-	10.6	-	-	5
T2	TH05	4.8	-	-	-	-	11.5	-	-	5
T3	TH05	7.5	-	-	-	-	17.0	-	-	5
T4	TH05	9.2	-	-	-	-	19.2	-	-	5
T5	TH05	10.8	-	-	-	-	18.8	-	-	5

Table 3.1.1-2. (continued 8/8).

Sample Number	Borehole Number	Depth Interval Top (ft)	Depth Interval Bottom (ft)	Particle Density (g/cc)	Bulk Density (g/cc)	Porosity %	Moisture Content (%, g/g)	Saturated Moisture Content (%, g/cc)	Vertical Hydraulic Conductivity (cm/s)	Reference[a]
T6	TH05	12.5	-	-	-	-	19.2	-	-	5
T7	TH05	14.2	-	-	-	-	17.9	-	-	5
T8	TH05	15.6	-	-	-	-	9.8	-	-	5

a. 1. Barraclough, et al. (1976)
2. McElroy and Hubbell (1990
3. Binda (1981)
4. Hubbell (1985)
5. Hubbell (1987)

Table 3.1.1-3. Air permeabilities for in situ moisture content (native state) and dry state of surficial sediments (from McElroy and Hubbell, 1990).

		Depth Interval			Air Permeability (md)	
Sample Number	Well Number	Top (ft)	Bottom (ft)	Moisture Content (%, g/g)	Air Permeability Native State	Air Permeability, Dry State
ST20	W09	6.0	7.0	17.9	66.0	3385.1
ST06	W24	7.4	8.3	19.4	2570.0	8260.0
ST10	W06	11.0	11.8	29.6	72.0	654.3

Three of the hydrogeologic properties, particle-size distribution, saturated hydraulic conductivity, and in situ moisture contents, are discussed next.

The particle-size distribution results show the surficial sediments are predominantly silts with significant clay content. Arithmetic means were calculated to determine the mean percent particle sizes for clay, silt, sand, and gravel using the data contained in Table 3.1.1–1. The mean percent grain sizes are presented in Table 3.1.1-4. They show the highest mean percentage is in the silt-size range (49.6%). This is in agreement with the geologic logs, which also record silt as the dominant soil texture.

Large variations in soil textures are shown by the results of the particle-size distribution analysis (Table 3.1.1-1). Clay contents ranged from 5.58 to 55.6%, silt contents from 15.4 to 74.6%, sands from 2.8 to 75.1%, and gravels from 0 to 21.1%. As an example, the clay content in Borehole 4, Samples 4-2 and 4-3, changes from 19.7% clay to 5.9% clay within a 2-ft vertical interval. The surficial sediments are highly heterogeneous, both vertically and laterally, which complicates the hydrologic characterization of these sediments.

As seen in Table 3.1.1-2, hydraulic conductivity values for the surficial sediments are limited in number. Measured hydraulic conductivities of the surficial sediments vary over four orders of magnitude, from 1.11E-08 to 6.94E-04 cm/s (Table 3.1.1-2). A mean hydraulic conductivity of 1.52E-04 cm/s was calculated by arithmetically averaging the 11 hydraulic conductivity values listed in Table 3.1.1-2, and the mean and standard deviation are shown in Table 3.1.1-4.

Table 3.1.1-4. Mean percent particle size, hydraulic conductivity, and moisture content of the surficial sediments.

	Percent Clay	Percent Silt	Percent Sand	Percent Gravel	Vertical Hydraulic Conductivity (cm/s)	Percent Moisture Content (g/g)
Mean	28.94	49.57	20.26	1.08	1.52E-04	16.0
Standard Deviation	13.84	14.71	19.58	3.39	2.44E-04	6.6

Soil from the spreading areas was brought in to recontour and cover sections of the SDA. The soil cover in the southwestern and south central portion of the SDA was sampled (Borghese, 1989, see Section 3.1.3) to collect hydraulic conductivity data for the soil cover. Samples were collected with thin-walled, 12.7-cm diameter Shelby tubes and analyzed for particle-size distribution and saturated hydraulic conductivity (at 4 points along the tube). The majority of the 14 samples were classified as silt-size, with mean vertical hydraulic conductivities ranging from 3.5E-05 to 4.9E-03 cm/s (Borghese, 1988). Hydraulic conductivities ranged up to two orders of magnitude between contiguous sample points within one sample tube, indicating the soil cover is very heterogeneous.

The mean hydraulic conductivities of the soil cover are within the range of the underlying surficial sediments and do not appear to act as a cap to moisture movement into the surficial sediments. The purpose of the soil cover material was for recontouring and subsidence problems and not to serve as a regulatory-compliant cap.

Gravimetric moisture content data from the surficial sediments range from 2.0 to 45.4% (shown in Table 3.1.1-2). There are significant lateral and vertical variations as seen in the following Table 3.1.1-5 (excerpts from Table 3.1.1-2). The 10-ft depth below land surface varies from 5.4 to 15.5% between Boreholes T23 and W11. Boreholes T23 and W23 are within 5 ft of each other, yet the 19-ft depth below land surface varies from 26.3 to 36.3% water content. The water contents within a vertical profile for Borehole W23 varied from 2.2 to 36.3%.

Differing soil textures, the influence of evapotranspiration, and the distance from the underlying basalt all appear to influence the soil moisture content. Sandy soils tend to hold less water than clay soils under unsaturated conditions, therefore, decreasing their water content. Evapotranspiration affects soils near the surface by moving water out of the sediments and into plants or the atmosphere. The basalt layer may act to impede the movement of water, therefore, allowing moisture to collect in the sediments directly over the basalt. This tends to increase the moisture content values of those sediments directly.

Table 3.1.1-5. Gravimetric moisture contents of surficial sediments showing lateral and vertical variations.

Borehole T23		Borehole W23		Borehole T11	
Depth (ft)	Moisture Content (%)	Depth (ft)	Moisture Content (%)	Depth (ft)	Moisture Content (%)
2.43	15.0	2.33	10.9	2.3	9.4
4.17	21.2	4.07	19.9	4.0	14.9
5.90	11.4	5.84	11.7	5.7	15.4
7.68	9.1	7.58	7.7	7.3	14.2
8.59	3.0	9.32	2.2	-	-
10.33	5.4	-	-	10.0	15.5
-	-	11.09	3.3	11.7	14.7
12.07	20.2	12.82	24.9	13.3	16.2
13.84	20.7	14.6	23.9	15.0	21.1
15.58	18.0	16.33	21.6	16.5	10.8
17.32	21.8	18.07	18.3	-	-
19.32	28.3	-	-	-	-
19.91	26.3	19.84	36.3	-	-

The area within the SDA disturbed by pits, trenches, soil vaults, and Pad A is estimated to be 39% of the total SDA area (Hubbell and Higgs, 1989). The soil characteristics in the disturbed portions of waste pits and trenches may be substantially different from the undisturbed areas, but no data are available yet for comparison.

Currently, hydraulic analysis of additional surficial sediment samples is forthcoming from the expansion of the NAT network (~30 samples). These samples include disturbed as well as undisturbed soils.

Soil textures of the surficial sediments are dominated by silts with significant clay content. Geologic borehole logs show that clay, sand, and gravel layers are present but are not laterally continuous. The silt, sand, gravel, and clay layers result in vertical and lateral heterogeneities within the surficial sediments.

Lateral and vertical variations in the soil properties are observed. Measured hydraulic conductivities of the surficial sediments vary over four orders of magnitude, from 1.11E-08 to 6.94E-04 cm/s. Gravimetric moisture content data from the surficial sediments range from 2.0% to 45.4%. Particle-size distributions show wide variations in silt, clay, and sand content. Unlike a homogeneous soil with predictable and uniform soil characteristics, SDA surficial sediments are heterogeneous with varying spatial characteristics.

3.1.2 Kaminsky, 1991

In Kaminsky, 1991, in situ estimates of hydraulic properties of surficial sediments adjacent to the RWMC were obtained from a field infiltration/drainage test. The study utilized a field plot, instrumented with tensiometers and two neutron probe access tubes, which was flooded for 24 hours, and then covered and allowed to drain. The unsaturated hydraulic properties were estimated by the instantaneous profile (K-θ) and the unit gradient (dK/dθ) methods and were analyzed using the FORTRAN code UNGRA. This program uses a non-linear, least -squares analysis to estimate the parameters of soil hydraulic properties, and fit analytical functions to observed retention and unsaturated hydraulic conductivity data. The soil water retention function was described using the equation of van Genuchten (1980), and the unsaturated hydraulic conductivity function was obtained by the combination of the van Genuchten retention function with the pore-size distribution model of Maulem (1976). Five different types of data sets were used in parameter estimation. These sets were: retention data alone, retention data with instantaneous profile K-θ data, K–θ alone, retention with unit gradient dK/dθ data, and unit gradient dK/dθ data alone. In the majority of cases, graphical results were similar between measured and predicted curves of both retention and hydraulic conductivity data, although hydraulic parameters estimated from curve-fitting showed little similarity. These plots also showed that unit gradient measurements can be substituted for the harder-to-obtain instantaneous profile measurements, and also provided results over a greater range of hydraulic conductivity values, even though tensiometer gradients were not always unity. The tables from Kaminsky, 1991 that are pertinent to this report, are repeated in Tables 3.1.2-1 to 3.1.2-7.

Table 3.1.2-1. Parameters determined by regression of the water redistribution equation ($\theta = at^b$) using unit gradient data (from Kaminsky 1991, Table 3). The variable t is time and a and b are empirical constants.

Depth (cm)	a	b	r^2 +	S_θ ++	Ks (cm/hr)
wt2 series (southern end of plot)					
6	0.3099	-0.1323	0.8964	0.1230	0.1491
21	0.3384	-0.0756	0.9440	0.0503	2.0203
36	0.3479	-0.0603	0.9566	0.0351	6.1159
51	0.3549	-0.0542	0.9641	0.0286	6.9936
67	0.3574	-0.0511	0.9619	0.0278	2.9389
82	0.3608	-0-0503	0.9544	0.0301	2. 7405
112	0.3618	-0.0501	0.9401	0.0346	1.6052
wt3 series (northern end of plot)					
10	0.3724	-0.1044	0.9098	0.0925	0.3309
25	0.3704	-0.0685	0.9495	0.0445	1.2756
41	0.3723	-0.0552	0.9694	0.0276	2.2342
56	0.3695	-0.0468	0.9697	0.0232	1.0932
71	0.3667	-0.0430	0.9647	0.0232	0.6356
86	0.3674	-0.0436	0.9488	0.0285	1.0259
117	0.3641	-0.0425	0.9377	0.0308	0.3103

+ Correlation coefficient r^2, is a measure of the validity of a model. Its value ranges from 0 to 1, with 1 being optimal.

++ Estimated standard error of the water content values. This value represents the deviation of the observed water contents from the values obtained from regression.

Table 3.1.2-2. Correlation of low n values with anomalously high Ks predictions (from Kaminsky 1991, Table 4).

Depth (cm)	Ks (cm/hr)	van Genucten's n	Type of data set
wt2 series (southern end of plot)			
36	150.80	1.09	θ(h)-dk/dθ
36	154.10	1.09	Dk/dθ only
51	82.11	1.1	θ(h)-Dk/dθ
67	57.70	1.10	θ(h)-Dk/dθ
67	57.30	1.10	Dk/dθ only
wt3 series (northern end of plot)			
25	448.5	1.09	θ(h) only
2.5	78.6	1.1	θ(h)-Dk/dθ
25	77.2	1.1	Dk/dθ only
41	1157.9	1.08	θ(h) only
41	36570	1.1	θ(h)-Dk/dθ
41	no convergence	1.1	Dk/dθ only
56	68.2	1.07	θ(h)-Dk/dθ
56	73.9	1.07	Dk/dθ only
71	14.5	1.1	θ(h)-Dk/dθ
71	14.6	1.1	Dk/dθ only
117	22.50	1.61	θ(h)-Dk/dθ
117	15.90	1.85	Dk/dθ only

Table 3.1.2-3. Summary of hydraulic parameters as estimated by UNGRA for WT2 series (southern side of plot) (from Kaminsky 1991, Table A1a).

Depth cm	IPM K-θ from x-y cm layer	parameter	h-θ only	h-θ-K	K-θ only	h-θ-Dk/dθ	Dk/dθ only
112	82-112	θ_r	0	0.1717	0.2152	0	0
		θs	0.3778	0.3616	0.3616	0.3578	0.3578
		α (cm^{-1})	0.0059	0.0104	0.0101	0.0108	0.008
		n	1.6392	1.5905	1.7402	1.2198	1.218
		K_s (cm/hr)	0.7121	0.8361	0.6167	3.4269	3.5091
		r^2	0.9933	0.9252	0.9355	0.9355	0.9361
82	67-82	θ_r	0.04712	0.0105	0.2056	0	0
		θs	0.37342	0.3617	0.3619	0.3712	0.3715
		α (cm^{-1})	0.00477	0.0078	0.0086	0.0145	0.0088
		n	1.6348	1.2791	1.439	1.1951	1.1863
		K_s (cm/hr)	1.04653	1.3029	1.2657	4.012	4.7527
		r^2	0.9913	0.9778	0.9481	0.9683	0.9697
67	51-67	θ_r	0	0.1829	0.1869	0	0
		θs	0.3734	0.3651	0.3651	0.3734	0.373
		α (cm^{-1})	0.0063	0.0116	0.0095	0.0317	0.0213
		n	1.3129	1.4022	1.4083	1.1037	1.1035
		K_s (cm/hr)	1.0544	0.896	0.8974	57.7081	57.3198
		r^2	0.9759	0.9914	0.9667	0.955	0.9534
51	51-67	θ_r	0	0.1065	0.1869	0	0.1897
		θs	0.38882	0.3638	0.3651	0.3926	0.3926
		α (cm^{-1})	0.01085	0.0076	0.0087	0.0529	0.0228
		n	1.21329	1.308	1.4083	1.1027	1.2991
		K_s (cm/hr)	5.27338	0.8591	0.8974	82.11	9.4611
		r^2	0.991	0.9905	0.9667	0.9749	0.9301
36	36-51	θ_r	0	0.1514	0.202	0	0
		θs	0.3788	0.3709	0.3757	0.3916	0.3918
		α (cm^{-1})	0.02196	0.0115	0.0157	0.0744	0.0829
		n	1.13105	1.3303	1.456	1.0905	1.0904
		K_s (cm/hr)	9.31	0.6798	0.7188	150.82	154.05
		r^2	0.981	0.9906	0.9508	0.9798	0.9763
21	21-36	θ_r	0	0.0546	0.0872	0	0
		θs	0.37212	0.3712	0.3714	0.3813	0.3814
		α (cm^{-1})	0.01311	0.0199	0.0144	0.0303	0.0315
		n	1.17774	1.2394	1.2704	1.1276	1.1273
		K_s (cm/hr)	1.99121	0.9398	0.8468	9.8153	9.9694
		r^2	0.9906	0.9886	0.9444	0.9924	0.9898
6	0-21	θ_r	0	0	0	0	0
		θs	0.29567	0.3144	0.3354	0.2923	0.2923
		α (cm^{-1})	0.01276	0.0193	0.0461	0.0109	0.0154
		n	1.53943	1.4591	1.3559	1.5979	1.5983
		K_s (cm/hr)	0.04293	0.0949	0.3811	0.1712	0.1713
		r^2	0.9669	0.979	0.9188	0.9871	0.9753

Table 3.1.2-4. Summary of hydraulic parameters as estimated by UNGRA for WT3 series (northern side of plot) (from Kaminsky 1991, Table A1b).

Depth cm	IPM K-θ from x-y cm layer	parameter	h-θ only	h-θ-K	K-θ only	h-θ-Dk/dθ	Dk/dθ only
117	86-117	θ_r	0.1897	0.2107	0	0	0
		θs	0.363	0.3481	0.3471	0.3366	0.3388
		α (cm^{-1})	0.0073	0.0118	0.0054	0.0035	0.003
		n	2.3048	1.5249	1.2511	1.6098	1.8526
		K_S (cm/hr)	0.1301	0.6322	0.7188	22.54	15.863
		r^2	0.9649	0.9417	0.8089	0.8946	0.4652
86	71-86	θ_r	0	0	0.0997	0	0
		θs	0.3789	0.3556	0.3567	0.3627	0.3629
		α (cm^{-1})	0.0064	0.009	0.0078	0.0112	0.008
		n	1.4703	1.2677	1.2887	1.2435	1.2301
		K_S (cm/hr)	0.7882	0.5628	0.7925	1.6439	1.9454
		r^2	0.9865	0.9587	0.8417	0.9528	0.9535
71	56-71	θ_r	0	0.208	0.2154	0	0
		θs	0.3589	0.3593	0.359	0.3582	0.3582
		α (cm^{-1})	0.0055	0.0142	0.0154	0.0201	0.0191
		n	1.2736	1.3773	1.4025	1.0992	1.099
		K_S (cm/hr)	0.9696	1.2043	1.0913	14.495	14.627
		r^2	0.9815	0.9757	0.9163	0.9163	0.9635
56	41-56	θ_r	0	0.262	0.2795	0	0
		θs	0.3631	0.374	0.3777	0.3713	0.3715
		α (cm^{-1})	0.0069	0.0183	0.0136	0.0611	0.0495
		n	1.1682	1.5789	1.7593	1.0688	1.068
		K_S (cm/hr)	3.7007	2.2931	2.4587	68.2153	73.862
		r^2	0.9853	0.974	0.9447	0.9376	0.9344
41	25-41	θ_r	0	0.2889	0.2891	0.0946	0.089
		θs	0.4092	0.3901	0.3901	0.4754	0.7858
		α (cm^{-1})	0.1333	0.0137	0.0169	1.1512	no convergence
		n	1.0784	3.4322	3.52	1.1017	1.0982
		K_S (cm/hr)	1157.90	1.2367	1.2068	36570.	no convergence
		r^2	0.975	0.9593	0.8816	0.9734	0.9717
25	10-25	θ_r	0	0.0355	0.0389	0	0
		θs	0.4037	0.3752	0.3752	0.3876	0.3874
		α (cm^{-1})	0.1675	0.0057	0.011	0.0744	0.0628
		n	1.0866	1.3852	1.3934	1.0961	1.0961
		K_S (cm/hr)	448.48	0.9273	0.9057	78.61	77.205
		r^2	0.9297	0.9893	0.9537	0.984	0.9802
10	0-25	θ_r	0	0	0	0	0
		θs	0.3642	0.3702	0.37	0.3667	0.3668
		α (cm^{-1})	0.0097	0.01	0.0119	0.0126	0.0118
		n	1.5192	1.5135	1.4729	1.4307	1.4268
		K_S (cm/hr)	0.1221	0.1498	0.1682	0.5477	0.5644
		r^2	0.9926	0.9762	0.7698	0.9893	0.9828

Table 3.1.2-5. Instantaneous profile hydraulic conductivities as a function of moisture content for WT2 Series (Kaminsky, 1991, Appendix B, Table 1a).

0-21 cm layer		21-36 cm layer		36-51 cm layer	
θ	K(θ) (cm/hr)	θ	K(θ) (cm/hr)	θ	K(θ) (cm/hr)
0.3452	0.6930	0.3756	1.2534	0.3844	1.1591
0.32945	0.1302	0.3771	0.7750	0.3759	0.6563
0.3421	0.3744	0.3695	0.2785	0.37685	0.401
0.3277	0.1272	0.3711	0.4912	0.36625	0.2219
0.32445	0.0748	0.3629	0.1457	0.38345	0.6768
0.32445	0.0748	0.3715	0.6671	0.3707	0.3688
0.3198	0.07136	0.3600	0.09216	0.36065	0.07309
0.3161	0.016455	0.3578	0.03365	0.36335	0.08061
0.3106	0.04238	0.3533	0.05904	0.35755	0.04697
0.3189	0.03965	0.34975	0.03561	0.35795	0.06055
0.31145	0.03395	0.3551	0.04990	0.3507	0.0577
0.3038	0.02456	0.3524	0.05272	0.3477	0.02446
0.30845	0.0345	0.3397	0.02911	0.33605	0.02638
0.3030	0.01617	0.3271	0.00525	0.3403	0.02914
0.3077	0.02615	0.3189	0.00805	0.3279	0.00589
0.2883	0.01758	0.3141	0.00488	0.3228	0.007765
0.2713	0.003112	0.3125	0.00149	0.3196	0.004797
0.2610	0.004789	0.3063	0.00349	0.3148	0.001787
0.2518	0.003425	0.3018	0.00221	0.3090	0.005048
0.24635	0.000851	0.30115	0.00440	0.3075	0.00136
0.2400	0.001315	0.30065	0.002365	0.3081	0.00603
0.2366	0.001104	0.29935	0.004116	0.3066	0.003656
0.23855	0.001244	0.2963	0.00787	0.3067	0.00261
0.2325	0.001828	0.2934	0.01192	0.30145	0.007806
0.2340	0.001884	0.28895	0.003581	0.2970	0.006218
0.2294	0.001339		0.30405	0.008043	
0.2237	0.001331				
0.2267	0.001132				

Table 3.1.2-6. Instantaneous profile hydraulic conductivities as a function of moisture content for WT2 Series (from Kaminsky 1991, Appendix B).

0-21 cm layer		21-36 cm layer		36-51 cm layer		51-67 cm layer		67-82 cm layer		82-114 cm layer	
θ	K(θ) (cm/hr)	θ	K(θ) (cm/hr)	θ	K(θ) (cm/hr)	θ	K(θ) (cm/hr)	θ	K(θ) (cm/hr)	θ	K(θ) (cm/hr)
0.3452	0.6930	0.3756	1.2534	0.3844	1.1591	0.3837	0.9929	0.3704	1.5015	0.3593	1.3180
0.32945	0.1302	0.3771	0.7750	0.3759	0.6563	0.3702	1.0074	0.3638	1.2692	0.3610	0.9591
0.3421	0.3744	0.3695	0.2785	0.37685	0.401	0.3794	0.7901	0.3706	1.4004	0.3614	0.9214
0.3277	0.1272	0.3711	0.4912	0.36625	0.2219	0.3746	0.8389	0.3648	0.9783	0.3582	0.5981
0.32445	0.0748	0.3629	0.1457	0.38345	0.6768	0.3636	0.4849	0.3614	0.9045	0.3601	0.7246
0.32445	0.0748	0.3715	0.6671	0.3707	0.3688	0.3651	0.6710	0.3611	0.9866	0.3579	0.7153
0.3198	0.07136	0.3600	0.09216	0.36065	0.07309	0.3575	0.1248	0.3590	0.2321	0.3584	0.1026
0.3161	0.016455	0.3578	0.03365	0.36335	0.08061	0.3626	0.2715	0.3616	0.5539	0.3614	0.3650
0.3106	0.04238	0.3533	0.05904	0.35755	0.04697	0.3552	0.1117	0.3565	0.3085	0.3550	0.3141
0.3189	0.03965	0.34975	0.03561	0.35795	0.06055	0.3562	0.1161	0.3562	0.2470	0.3536	0.2122
0.31145	0.03395	0.3551	0.04990	0.3507	0.0577	0.3501	0.1288	0.3532	0.3052	0.3525	0.1844
0.3038	0.02456	0.3524	0.05272	0.3477	0.02446	0.3514	0.1245	0.3560	0.3022	0.3372	0.2285
0.30845	0.0345	0.3397	0.02911	0.33605	0.02638	0.3449	0.0359	0.3488	0.0996	0.3508	0.2007
0.3030	0.01617	0.3271	0.00525	0.3403	0.02914	0.3483	0.0907	0.3451	0.1181	0.3460	0.1766
0.3077	0.02615	0.3189	0.00805	0.3279	0.00589	0.3487	0.0854	0.3495	0.1504	0.3477	0.1754
0.2883	0.01758	0.3141	0.00488	0.3228	0.007765	0.3370	0.0406	0.3493	0.1728	0.3486	0.1805
0.2713	0.003112	0.3125	0.00149	0.3196	0.004797	0.3374	0.0486	0.3395	0.0663	0.3401	0.1252
0.2610	0.004789	0.3063	0.00349	0.3148	0.001787	0.3290	0.0125	0.3393	0.0862	0.3410	0.1370
0.2518	0.003425	0.3018	0.00221	0.3090	0.005048	0.3233	0.0161	0.3304	0.0331	0.3301	0.0755
0.24635	0.000851	0.30115	0.00440	0.3075	0.00136	0.3190	0.0190		0.3228	0.1194	
0.2400	0.001315	0.30065	0.002365	0.3081	0.00603	0.3130	0.0054		0.3171	0.1132	
0.2366	0.001104	0.29935	0.004116	0.3066	0.003656				0.3117	0.0829	
0.23855	0.001244	0.2963	0.00787	0.3067	0.00261						
0.2325	0.001828	0.2934	0.01192	0.30145	0.007806						
0.2340	0.001884	0.28895	0.003581	0.2970	0.006218						
0.2294	0.001339		0.30405	0.008043							
0.2237	0.001331										
0.2267	0.001132										

Table 3.1.2-7. Instantaneous profile hydraulic conductivities as a function of moisture content for WT3 Series (from Kaminsky 1991, Appendix B).

0-10 cm layer		10-25 cm layer		25-41 cm layer		41-56 cm layer	
θ	K(θ) (cm/hr)	θ	K(θ) (cm/hr)	θ	K(θ) (cm/hr)	θ	K(θ) (cm/hr)
0.3748	0.4246	0.3900	0.81288	0.4062	0.3353	0.3845	1.776
0.37055	0.2783	0.3767	0.9530	0.3925	1.6040	0.3848	3.312
0.36135	0.1594	0.3772	1.0670	0.3985	2.6340	0.3770	1.654
0.3568	0.01286	0.3617	0.1655	0.3772	0.8316	0.37845	2.538
0.3610	0.0910	0.3750	0.6463	0.3908	1.7929	0.3662	0.4642
0.3560	0.01154	0.3583	0.06635	0.3664	0.2241	0.3725	0.8807
0.3563	0.0120	0.3605	0.1011	0.3741	0.4367	0.36065	0.2429
0.3513	0.03652	0.3537	0.1167	0.3602	0.2032	0.3652	0.3034
0.3518	0.02968	0.35495	0.1029	0.3633	0.2089	0.3557	0.2317
0.3427	0.04475	0.34845	0.1185	0.3559	0.1674	0.3567	0.2377
0.3469	0.04031	0.3518	0.1175	0.3590	0.1867	0.3518	0.1118
0.33415	0.01872	0.34245	0.06519	0.3529	0.1061	0.3492	0.3178
0.32755	0.01185	0.32865	0.09411	0.3410	0.2423	0.34785	0.07036
0.3239	0.00576	0.3161	0.03204	0.3289	0.0633	0.35045	0.1936
0.32635	0.008795	0.3258	0.06295	0.33895	0.1550	0.34145	0.01892
0.31145	0.008065	0.3133	0.01605	0.3286	0.01396	0.3333	0.02116
0.28805	0.0054	0.3064	0.01548	0.3287	0.0050	0.3304	0.02442
0.2676	.004406	0.2925	0.01327	0.3234	0.01977	0.3232	0.01153
0.2434	.002605	0.2760	.006553	0.3154	.009536	0.3258	.006972
0.2436	0.001994	0.27705	.004878	0.31765	.006326		

Table 3.1.2-7. (continue) Instantaneous profile hydraulic conductivities as a function of moisture content for WT3 Series (from Kaminsky 1991, Appendix B).

56-71 cm layer		71-86 cm layer		86-117 cm layer	
θ	K(θ) (cm/hr)	θ	K(θ) (cm/hr)	θ	K(θ) (cm/hr)
0.3612	0.9662	0.3560	0.7892	0.3463	0.9176
0.3597	1.6950	0.3567	1.4730	0.3485	1.77
0.3598	0.9585	0.3565	0.7824	0.3483	0.7336
0.3602	1.3416	0.3589	1.1610	0.34945	1.281
0.3571	0.3526	0.3572	0.3578	0.3474	0.4777
0.3566	0.5873	0.3550	0.4904	0.3464	0.569
0.3535	0.1373	0.35505	0.1077	0.3445	0.123
0.35665	0.1919	0.3566	0.1792	0.3479	0.2194
0.3511	0.1735	0.3535	0.1465	0.3465	0.1756
0.3516	0.1558	0.3541	0.1290	0.3460	0.1507
0.3460	0.08078	0.3497	0.0790	0.3442	0.1152
0.3425	0.2275	0.3457	0.1806	0.3402	0.2237
0.34305	0.04107	0.3444	0.02999	0.3381	0.03705
0.3433	0.1375	0.3456	0.1075	0.3398	0.1328
0.3370	0.02904	0.33665	0.03247	0.3316	0.05151
0.3292	0.02353	0.3264	0.02008	0.3240	0.02512
0.32755	0.02836	0.32275	0.02498	0.3180	0.03121
0.3214	0.01417	0.31395	0.01455	0.3042	0.01851
0.32385	0.00945	0.31585	0.009732	0.3069	0.01197

3.1.3 Borghese, 1988

Hydraulic characteristics of the soil cover at the Subsurface Disposal Area were examined and presented in Borghese, 1988. Laboratory methods are used to determine the characteristics of: saturated hydraulic conductivity (K), grain size distribution, dry bulk density, and porosity. The range of saturated vertical hydraulic conductivity of the samples tested is 7.7×10^{-6} to 8.4×10^{-2} cm/s. The analysis of grain sizes indicate that the samples are predominantly silt size. Dry bulk densities range from 1.0 to 1.5 g/cm^3. Laboratory porosity values ranged from 25 to 38 percent. The highest K values were determined for a depth interval of about 5 to 15 cm below land surface for 45 percent of the tested samples. A depth of about 15 to 25 cm has the highest bulk density for 60 percent of the tested samples. The tables from Borghese, 1988 that are pertinent to this report, are repeated in Tables 3.1.3-1 to 3.1.3-6.

Table 3.1.3-1. Percent by weight of sample particles finer than 0.074 mm (from Borghese, 1988, Table 2).

Sample Number	Interval Number	Cumulative Weight Percent Passing 0.074 mm
1	1	37.60
	2	50.3
	3	32.0
	4	24.70
2	1	27.9
	2	25.90
	3	51.70
	4	27.70
3	1	39.50
	2	39.2
	3	23.0
	4	7.60
TS2	1	56.00
	2	42.0
	3	35.3
	4	43.7
6	1	9.40
	2	14.00
	3	8.60
	4	13.30
10	1	47.50
	2	64.40
	3	38.20
	4	51.30
11	1	38.60
	2	38.80
	3	35.10
	4	28.70
13	1	37.3
	2	29.3
	3	19.60
	4	9.40
14A	1	30.90
	2	37.3
	3	27.5
	4	42.6

Table 3.1.3-1. Percent by weight of sample particles finer than 0.074 mm (from Borghese, 1988, Table 2) (continued).

Sample Number	Interval Number	Cumulative Weight Percent Passing 0.074 mm
16	1	28.5
	2	50.10
	3	42.80
	4	37.2
20	1	43.0
	2	53.60
	3	56.50
	4	20.2
26	1	634
	2	58.20
	3	52.70
	4	34.7
30	1	76.8
	2	61.40
	3	32.2
	4	52.30

Table 3.1.3-2. Range and average of porosities (from Table 3 in Borghese, 1988).

	n1 in percent			n1 in percent		
	Max	Min	Average	Max	Min	Average
Method one	38	25	33	39	28	35
Method two						
ps=2.65 g/cm^3	51	42	45	51	43	48
ps=2.40	46	38	40	46	38	43
ps=2.75	53	45	46	53	45	50

Table 3.1.3-3. Summary of hydraulic characteristics (from Table 4 in Borghese, 1988).

Sample number	Geometric mean of K cm/s	n1 percent	pbl3 g/cm	Average of intervals 1-4 cumulative weight percent passed 200 sieve
1	2.4×10^{-4}	25	1.40	36.2
2	1.5×10^{-4}	36	--	33.3
3	1.2×10^{-4}	--	1.50	19.8
TS2	4.9×10^{-3}	31	1.40	44.3
6	2.0×10^{-4}	38	1.30	11.3
8	7.0×10^{-5}	--	--	--
10	5.0×10^{-5}	35	1.50	50.4
11	1.5×10^{-3}	33	--	35.3
13	4.4×10^{-5}	29	1.50	23.9
14A	1.7×10^{-4}	36	1.50	34.6
16	1.4×10^{-4}	34	1.50	39.7
20	3.9×10^{-5}	30	1.40	43.3
26	3.7×10^{-5}	30	1.50	52.3
30	1.9×10^{-4}	33	1.40	55.7

Table 3.1.3-4. Saturated vertical hydraulic conductivity (from Appendix D of Borghese, 1988).

		K (cm/sec) at 20° C				
		Interval Number				
	Observation Number	1	2	3	4	5
Sample 1	15	1.37E-03	1.52E-04	4.10E-04	1.03E-03	3.73E-04
	16	1.03E-03	1.14E-04	3.08E-04	7.69E-04	2.80E-04
	17	1.03E-03	1.14E-04	3.08E-04	7.69E-04	2.80E-04
	22	6.55E-04	1.36E-04	2.73E-04	8.13E-04	2.91E-04
	30	7.72E-04	1.34E-04	2.21E-04	3.43E-04	2.47E-04
	31	6.87E-04	1.19E-04	1.96E-04	3.05E-04	2.20E-04
	39	6.67E-04	1.60E-04	3.08E-04	6.67E-04	3.20E-04
	44	4.45E-04	1.62E-04	7.12E-04	2.23E-04	2.79E-04
	47	4.69E-04	1.70E-04	5.36E-04	2.83E-04	3.00E-04
	57	4.38E-04	1.40E-04	5.85E-04	2.70E-04	2.70E-04
	58	4.28E-04	1.37E-04	5.71E-04	2.64E-04	2.64E-04
	60	2.06E-04	5.15E-05	1.12E-04	1.12E-04	9.51E-05
	64	4.62E-04	1.54E-04	2.13E-04	3.96E-04	2.52E-04
	65	3.94E-04	1.97E-04	2.73E-04	5.91E-04	3.08E-04
	76	7.78E-04	1.56E-04	3.11E-04	1.94E-04	2.49E-04
	73	5.21E-04	1.16E-04	1.49E-04	1.60E-04	1.70E-04
	79	6.65E-04	1.48E-04	1.90E-04	2.05E-04	2.17E-04
	80	5.22E-04	1.16E-04	1.49E-04	1.61E-04	1.70E-04
	85	6.58E-04	1.32E-04	1.88E-04	2.63E-04	2.19E-04
Sample 2	67	1.39E-04	1.48E-03	6.26E-05	5.56E-04	1.56E-04
	73	1.08E-04	5.14E-04	6.63E-05	8.22E-04	1.46E-04
	75	1.08E-04	5.14E-04	6.63E-05	8.22E-04	1.46E-04
	77	1.12E-04	5.33E-04	6.88E-05	8.53E-04	1.51E-04
Sample 3	14		8.20E-05			1.63E-04
	16		8.07E-05	1.16E-04	2.44E-04	1.60E-04
	19		8.04E-05	1.23E-04	2.52E-04	1.64E-04
	22		7.45E-05	1.15E-04	2.07E-04	1.48E-04
	24		7.52E-05	1.16E-04	2.10E-04	1.50E-04
	26		7.97E-05	1.22E-04	2.31E-04	1.59E-04
	28		7.84E-05	1.21E-04	2.22E-04	1.57E-04
	30		7.77E-05	1.17E-04	2.00E-04	1.51E-04
	32		7.71E-05	1.16E-04	1.98E-04	1.50E-04
	33		7.58E-05	1.14E-04	1.95E-04	1.48E-04
Sample TS2	52	6.10E-02	1.02E-02	1.22E-03	3.39E-03	3.26E-03
	53	6.78E-02	1.13E-02	1.36E-03	3.77E-03	3.63E-03
	55	8.44E-02	1.41E-02	1.51E-03	5.27E-03	4.28E-03
	56	7.84E-02	1.31E-02	1.40E-03	4.90E-03	3.98E-03
	57	8.14E-02	1.36E-02	1.45E-03	5.09E-03	4.13E-03
	59	1.86E-02	1.24E-02	1.77E-03	4.38E-03	4.32E-03
	60	1.80E-02	1.20E-02	1.71E-03	4.23E-03	4.18E-03
	61	1.79E-02	1.19E-02	1.70E-03	4.20E-03	4.15E-03
	65	1.80E-02	2.10E-02	3.15E-03	9.01E-03	7.55E-03
	66	1.78E-02	2.07E-02	3.11E-03	8.89E-03	7.45E-03

Table 3.1.3-4. Saturated vertical hydraulic conductivity (from Appendix D of Borghese, 1988) continued.

	Observation Number	K (cm/sec) at 20° C Interval Number 1	2	3	4	5
	68	1.87E-02	2.19E-02	3.28E-03	9.37E-03	7.85E-03
	69	1.84E-02	2.14E-02	3.21E-03	9.13E-03	7.69E-03
	72	8.76E-03	3.07E-02	2.36E-03	6.13E-03	5.47E-03
	73	8.72E-03	3.05E-02	2.35E-03	6.10E-03	5.44E-03
	74	9.55E-03	3.34E-02	2.57E-03	6.68E-03	5.96E-03
	75	8.72E-03	3.05E-02	2.35E-03	6.10E-03	5.44E-03
	77	9.52E-03	3.33E-02	2.38E-03	6.06E-03	5.56E-03
	73	9.43E-03	3.30E-02	2.36E-03	6.00E-03	5.51E-03
	79	9.47E-03	3.32E-02	2.37E-03	6.03E-03	5.54E-03
	81	8.72E-03	3.05E-02	2.35E-03	6.10E-03	5.44E-03
	82	7.85E-03	2.75E-02	2.11E-03	5.49E-03	4.89E-03
	83	8.28E-03	2.90E-02	2.23E-03	5.80E-03	5.17E-03
	84	8.28E-03	2.90E-02	2.23E-03	5.80E-03	5.17E-03
	86	7.75E-03	2.71E-02	2.26E-03	5.43E-03	5.06E-03
	87	6.82E-03	2.39E-02	1.99E-03	4.77E-03	4.45E-03
	88	6.46E-03	2.26E-02	1.68E-03	4.52E-03	4.22E-03
	91	8.76E-03	2.19E-02	2.09E-03	3.98E-03	4.51E-03
	92	8.76E-03	2.19E-02	2.09E-03	3.98E-03	4.51E-03
	93	8.76E-03	2.19E-02	2.09E-03	3.98E-03	4.51E-03
	95	1.27E-02	6.33E-02	2.11E-03	6.33E-03	5.52E-03
	96	1.21E-02	6.03E-02	2.01E-03	6.03E-03	5.25E-03
	97	1.21E-02	6.03E-02	2.01E-03	6.03E-03	5.25E-03
	99	9.52E-03	4.76E-02	2.16E-03	2.65E-03	4.15E-03
	100	8.33E-03	4.17E-02	1.89E-03	2.31E-03	3.63E-03
	101	8.93E-03	4.46E-02	2.03E-03	2.48E-03	3.89E-03
Sample	62	3.21E-04	1.80E-04	1.50E-03	1.22E-04	2.28E-04
6	66	2.98E-04	1.79E-04	1.12E-03	1.21E-04	2.21E-04
	68	2.45E-04	1.57E-04	1.96E-03	8.72E-05	1.78E-04
	70	2.50E-04	1.60E-04	2.00E-03	8.90E-05	1.82E-04
	72	2.60E-04	1.66E-04	2.08E-03	9.25E-05	1.89E-04
Sample	37		2.26E-05	2.50E-05	3.75E-05	3.65E-05
8	38		2.38E-05	2.64E-05	3.96E-05	3.85E-05
	42		3.19E-05	4.28E-05	5.81E-05	5.66E-05
	44		2.94E-05	3.95E-05	5.36E-05	5.22E-05
	46		2.49E-05	4.36E-05	4.98E-05	4.85E-05
	48		3.73E-05	6.03E-05	7.89E-05	7.13E-05
	49		3.54E-05	5.72E-05	7.48E-05	6.77E-05
	51		3.82E-05	6.18E-05	8.09E-05	7.31E-05
	53	1.44E-03	3.96E-05	6.26E-05	8.81E-05	7.51E-05
	54	1.48E-03	4.07E-05	6.43E-05	9.05E-05	7.72E-05
	56	5.48E-04	2.65E-05	6.33E-05	6.86E-05	5.72E-05
Sample	35	2.39E-04	2.39E-04		1.49E-05	5.88E-05
10	38	2.12E-04	2.12E-04		1.37E-05	5.48E-05

Table 3.1.3-5. Dry bulk density (from Appendix F in Borghese, 1988).

Sample Number	Interval Number	ρ_b lab g/cm^3	ρ_b field complete sample g/cm^3
1	1	1.3	1.3
	2	1.5	
	3	1.3	
	4	1.6	
	5	1.4	
2	1	-	
	2	1.5	
	3	-	
	4	-	
	5	-	
3	1	1.3	1.4
	2	1.6	
	3	1.3	
	4	1.6	
	5	1.5	
TS2	1	1.3	---
	2	1.4	
	3	1.3	
	4	1.5	
	5	1.4	
6	1	1.3	1.3
	2	1.6	
	3	1.4	
	4	1.2	
	5	1.3	
8	1	-	
	2	-	
	3	-	
	4	-	
	5	-	
10	1	1.4	1.4
	2	1.3	
	3	1.7	
	4	1.5	
	5	1.5	
11	1		
	2	1.6	
	3		
	4		
	5		

Table 3.1.3-5. Dry bulk density (from Appendix F in Borghese, 1988) continued.

Sample Number	Interval Number	ρ_b lab g/cm^3	ρ_b field complete sample g/cm^3
13	1	1.1	1.4
	2	1.8	
	3	1.4	
	4	1.9	
	5	1.5	
14A	1	1.4	1.4
	2	1.7	
	3	1.6	
	4	1.4	
	5	1.5	
16	1	1.4	1.5
	2	1.7	
	3	1.5	
	4	1.6	
	5	1.5	
20	1	1.0	1.3
	2	1.8	
	3	1.3	
	4	1.6	
	5	1.4	
26	1	1.3	1.4
	2	1.9	
	3	1.7	
	4	1.3	
	5	1.5	
30	1	1.4	1.4
	2	1.5	
	3	1.4	
	4	1.4	
	5	1.4	

Table 3.1.3-6. Porosity of each sample (in %) (from Appendix G in Borghese, 1988).

Sample Number	Porosities in percent		
	Method one	Method two	
	n_l	n_l	n_f
1	25	47	51
2	36		
3	-	43	47
TS2	31	47	--
6	38	51	51
8	-		
10	35	43	47
11	33		
13	29	43	47
14A	36	43	47
16	34	43	43
20	30	47	51
26	30	43	47
30	33	47	47

Method one described on page 33 of text.
Method two described on page 34 of text.

3.1.4 Shakofsky, 1993

Shakofsky, 1993 considers the changes in soil properties induced by the construction of a simulated waste burial trench were measured at a radioactive waste disposal site in the semi-arid southeast region of Idaho. Samples of an aridisol soil were collected, using a hydraulically-driven sampler to minimize sample disruption, from both a simulated waste trench and an undisturbed area nearby.

Results show an undisturbed profile with distinct horizons, whereas in the waste trench these layers are absent. Porosity was increased in the disturbed cores, and, correspondingly, saturated hydraulic conductivities were higher. Unsaturated hydraulic conductivities for the undisturbed cores were typically greater than the disturbed cores at higher water contents (greater than 0.32). At lower water contents a majority of the disturbed cores have greater hydraulic conductivities. In general the vertical movement of water is retarded in a layered medium, suggesting that the construction of the landfill has destroyed impediments to downward flow.

The tables from Shakofsky, 1993 that are pertinent to this report are repeated in Tables 3.1.4-1 and 3.1.4-2. No table of the hydraulic conductivities versus moisture content is given but Figure 15 in Shakofsky, 1993 shows the relationship.

Table 3.1.4-1. Aggregate distribution of soil samples (from Table 2 in Shakofsky, 1993).

Hole I.D.	Depth (cm)	>4.0 mm	4.0 - 2.0 mm	2.0 - 1.0 mm	<1.0 mm
Undisturbed					
Anchor A	17-23	12.2	18.7	13.3	55.8
Anchor A	33-33	30.7	13.4	12.0	44.0
Anchor A	41-48	34.5	12.3	12.2	41.1
Hole 25	78-85	22.5	14.5	14.4	51.4
Hole 25	120-126	23.6	15.7	13.9	46.7
Hole 25	131-138	31.9	20.9	13.4	33.8
Hole 25	155-162	50.7	16.5	12.1	20.8
Hole 25	186-192	52.2	14.0	11.6	22.2
Hole 25	209-217	23.7	15.8	18.3	42.3
Hole 25	255-261	9.5	13.5	18.6	53.4
Hole 25	328-332	14.7	20.9	21.3	43.2
Disturbed					
Anchor D	20-30	17.9	10.8	11.4	59.9
Anchor D	37-45	17.4	13.4	14.0	55.2
Anchor D	50-59	18.4	12.0	13.7	56.0
Hole 28	55-62	16.4	14.3	14.3	55.0
Hole 28	79-87	17.0	13.7	15.0	54.4
Hole 27	123-134	20.4	16.8	14.7	48.1
Hole 28	158-163	26.4	16.5	15.7	41.4
Hole 28	187-197	31.7	15.3	15.6	37.4
Hole 29	211-219	32.6	17.4	15.1	34.8
Hole 27	348-357	45.2	17.9	13.7	23.2

Table 3.1.4-2. Summery of soil properties (from Shakofsky, 1993, Table 4).

Hole No.	Sample No.	Depth (cm)	Bulk Density (g/cm3)	Clay %	Field theta	Porosity	Ksat (cm/s)
Undisturbed							
9	2	18	1.4	13.7	0.1052	0.4716	-
3	13	18	1.392	-	0.1752	0.4746	-
17	9	27	1.427	18.2	0.1478	0.4615	1.60E-03
14	1	33	1.478	17.7	-	0.4424	4.40E-04
14	8	75	1.372	19.1	0.1412	0.4821	5.50E-03
16	3	80	1.434	20.2	-	0.4589	3.30E-03
16	4	129	1.458	24.1	0.1827	0.4497	2.60E-03
26	B21	140	1.455	22.6	-	0.451	2.10E-03
25	B17	148	1.46	24.1	-	0.449	1.70E-03
16	5	175	1.407	25.1	0.2725	0.4691	5.60E-04
26	B24	223	1.387	20.1	-	0.4766	4.40E-04
16	6	225	1.246	23.9	0.262	0.5299	2.10E-03
25	B20	226	1.228	14.2	-	0.5367	2.30E-03
Disturbed							
12	1s	18	1.312	15.5	0.201	0.5015	-
6	7	18	1.247	14.8	0.1247	0.5294	-
21	17	29	1.52	19.2	0.2264	0.4299	5.50E-04
22	18	29	1.36	20.8	-	0.4869	2.30E-03
22	21	79	1.258	20.3	-	0.5254	5.50E-03
21	20	79	1.313	20.6	-	0.5044	9.20E-03
19	14	135	1.191	21.3	0.1664	0.5505	-
29	C12	147	1.387	20.4	-	0.564	4.40E-03
27	C8	148	1.325	19.8	-	0.5001	1.20E-02
27	C10	223	1.208	19.5	-	0.5441	6.00E-03
29	C17	237	1.175	19.3	-	0.5567	1.30E-02

3.1.5 Martian and Magnuson, 1994

A calibrated simulation study of moisture infiltration at NAT W02 and W06 was conducted by Martian and Magnuson, 1994 to obtain a reliable estimate of hydraulic parameters, which then could be used to extend the simulation period backwards and forwards in time. Extending simulation back in time permits evaluation of water movement, which previous disposal practices were subject to; extending the simulation forward in time with estimated meteorological conditions allows evaluation of future conditions.

The objective of the simulation study is to obtain a good match between simulated and field estimates of moisture contents and matric potentials at W06, and moisture contents at W02. Once this objective is met, the calibrated simulations will provide (a) a reliable estimate of the amount and timing of net infiltration at the two locations, (b) a validation of hydraulic properties measured from W06 core samples presented in McElroy and Hubbell (1990) and field scale estimates of hydraulic properties presented in McElroy (unpublished work, 1994) and (c) an insight into the soil physics occurring at the SDA (i.e., explain the role of the surface soil-basalt interface and the presence of perched water in some of the NATs).

NATs W02 and W06 were installed in the fall of 1986. The neutron access holes were hand-augured to the underlying basalt at 14.5 ft and 10.5 ft below land surface for holes W02 and W06, respectively. Carbon steel pipes were then installed leaving 2 ft of pipe extending above the ground (Hubbell et al., 1987). In addition to the neutron access holes, a tensiometer nest with instruments was installed at 3-, 6-, and 9-ft depths in a borehole located approximately 4 ft east of NAT W06. Table 3.1.5-1 provides a geologic description of layering in NAT W02 and the tensiometer access hole near NAT W06, which was recorded during their construction.

In situ soil moisture and matric potential data at the NAT W02 and W06 locations were collected monthly from November 1986 to November 1990. In December 1992, neutron probe access tube monitoring was resumed with more frequent monitoring during the spring when the majority of infiltration occurred from snowmelt and spring rains. The neutron probes were monitored at least once a week prior to the spring snowmelt in March 1993, and monitored every other day during the snowmelt and subsequent infiltration in March and early April. As the soil profile began to dry, monitoring frequency was reduced to about once a week in April through June, twice a month in July, and once a month during August and September (McElroy, 1993).

Table 3.1.5-1. Geologic log of NATs W02 and W06 (McElroy, 1993).

W02		W06	
Depth (ft)	Description	Depth (ft)	Description
0.0	Silty clay	0.0	Sandy silt
2.5	Silt	1.7	Sandy silt
4.3	Sandy silt	2.8	Sandy silt
6.0	Sand	4.3	Sandy silt
7.7	Silt	6.0	Sandy silt
9.5	Silt	7.7	Clayey sandy silt
11.2	Silt	9.3	Sandy silt
13.0	Clayey silt	11.0	Sandy silt
14.7	Basalt	11.8	Basalt

Results of the differencing (i.e., net and maximum and changes in moisture contents for 6-in. depth intervals at 1-ft increments) are presented in Table 3.1.5-2. Both net and maximum changes in moisture contents followed a generally decreasing trend with increasing depth in both NATs. These trends indicated that much of the infiltration occurs near the surface and also exits through the surface via evapotranspiration. The amounts by which net and maximum changes in moisture contents deviate from a decreasing trend are small compared to the gross infiltration amounts described in McElroy (1993). Furthermore, most areas that deviated from the decreasing infiltration with depth trend were in areas of relatively low conductivity with the exception of maximum infiltration in NAT W06. Lateral flow would most likely occur in areas of high conductivity immediately over areas of low conductivity. The appearance of higher infiltration amounts in low conductivity is probably due to water remaining longer in the low conductivity areas. These results suggest that lateral water movement does not appear to be a significant factor contributing to the increased infiltration occurring at NATs W02 or W06 during 1993.

Results of the differencing also indicate that the soil profiles in both NATs retained some of the water from the relatively large 1993 precipitation amount, which reflects the precipitation pattern previous to and during the period. The integration period consisted of a relatively wet year, which was proceeded by a dry year. Finally, it should be noted that this analysis for lateral flow is only a crude estimation. Steady-state lateral flow would not be seen by the differencing equation.

Table 3.1.5-2. Infiltrated water amounts at various depths for NATs W02 and W06 (1987–1989) (Table 2 from Martian and Magnuson, 1994).

Depth (ft)	Net infiltrated water (in.)		Maximum infiltrated water (in.)	
	W02	W06	W02	W06
1.0	0.25	0.41	1.55	1.85
2.0	0.29	0.46	1.44	1.34
3.0	0.13	0.50	1.62	1.04
4.0	0.05	0.46	0.20	1.09
5.0	0.22	0.33	0.35	1.17
6.0	0.17	0.25	0.26	1.25
7.0	0.00	0.18	0.04	0.71
8.0	0.00	0.14	0.04	0.67
9.0	0.08	0.24	0.11	0.78
10.0	-0.02	unknown	0.05	unknown
11.0	0.04	unknown	0.11	unknown
12.0	0.02	unknown	0.07	unknown
13.0	-0.02	unknown	0.01	unknown

Final estimates of soil hydraulic properties for NATs W02 and W06 are presented in Tables 3.1.5-3 and 3.1.5-4, respectively. Appendix B in Martian and Magnuson, 1994 contains the final UNSAT-H input decks used in the W02 and W06 simulations.

Table 3.1.5-3. Hydraulic properties for W02 (Table 5 from Martian and Magnuson, 1994).

Soil layer	K_S (cm/hr)	θ_s	θ_r	α (1/cm)	n	Soil layer description
1	0.9	.500	.060	.0100	1.600	Silt
2	6.7	.485	.055	.0175	1.838	Transition
3	12.5	.470	.049	.0250	2.075	Transition
4	18.3	.455	.044	.0325	2.313	Transition
5	24.1	.440	.038	.0400	2.550	Sand
6	16.7	.463	.065	.0350	2.230	Transition
7	9.3	.487	.093	.0300	1.910	Transition
8	1.9	.510	.120	.0250	1.590	Sandy silt
9	18.2	.455	.064	.0309	2.308	Transition
10	12.4	.470	.089	.0218	2.065	Transition
11	6.5	.485	.115	.0127	1.823	Transition
12	0.6	.500	.140	.0036	1.580	Silt
13	0.8	.503	.133	.0054	1.583	Transition
14	0.9	.507	.127	.0072	1.587	Transition
15	1.0	.510	.120	.0090	1.590	Sandy silt
16	1.0	.230	.015	.0384	1.474	Basalt

Table 3.1.5-4. Hydraulic properties for W06 (Table 6 from Martian and Magnuson, 1994).

Soil layer	K_S (cm/hr)	θ_s	θ_r	α (1/cm)	n	Soil layer description
1	11.4	.554	.038	.0155	1.800	Silty sand
2	9.8	.540	.064	.0147	1.763	Transition
3	8.2	.527	.089	.0139	1.725	Transition
4	6.6	.514	.115	.0131	1.688	Transition
5	5.0	.500	.140	.0123	1.650	Silt
6	7.5	.503	.133	.0169	1.630	Transition
7	10.0	.507	.127	.0216	1.610	Transition
8	12.5	.510	.120	.0262	1.590	Sandy silt
9	10.0	.507	.127	.0216	1.610	Transition
10	7.5	.503	.133	.0169	1.630	Transition
11	5.0	.500	.140	.0123	1.650	Silt
12	1.0	.230	.015	.0384	1.474	Basalt

The amount of water that infiltrated past the basalt interface is a good indication of aquifer recharge because this water has no chance of returning to the surface via evapotranspiration. This is primarily due to the depth of the interface and the fact that the moisture retention for the basalt is much lower than the silts at the same tensions. The yearly drainage is presented in Table 3.1.5-5 and 3.1.5-6.

Table 3.1.5-5. Yearly simulation drainage from NAT W02 (Table 7 from Martian and Magnuson, 1994).

Year	Drainage (cm)
1986	0.20
1987	0.25
1988	0.23
1989	0.21
1990	0.19
1991	0.18
1992	0.17
1993	0.16[a]

a. Drainage is for Jan. 1 through Aug.31.

The simulation results indicated that a total of 1.6 cm of recharge occurred during the simulation period (1986 to 1993) and that 0.12 cm of recharge occurred from the 1993 spring snowmelt (January through July). The latter amount compared favorably to the less than 3 cm estimated by McElroy (1993). Two drainage peaks can be seen, one during spring 1986 and the other during spring 1993. The two peaks represent the two wettest years during the simulation period. The time-dependent drainage plot illustrates that NAT W02 may respond to years with high precipitation amounts and not to individual spring infiltration events.

Most recharge occurring near NAT W06 appears to be a result of spring snowmelt. Three significant recharge events took place during the simulation period. These events took place in 1986, 1989, and 1993. A higher than average winter precipitation was experienced during these years with 1993 being the most dramatic year. During the spring-summer of 1993 (March 26 to July 25), the simulation predicted 36 cm of water passed through the basalt interface, which compares favorably to 28 cm of net downward drainage estimated by McElroy (1993). The time-dependent drainage shows a response every year and not just years with high infiltration, as did NAT W02. Total recharge over the simulation period was 87 cm, which was primarily due to the assumption of a snow berm proportional to winter precipitation amounts adjacent to NAT W06. Table 3.1.5-6 presents yearly drainage from NAT W06.

Table 3.1.5-6. Yearly simulation drainage from NAT W06 (Table 8 from Martian and Magnuson, 1994).

Year	Drainage (cm)
1986	21
1987	2
1988	1
1989	20
1990	5
1991	1
1992	2
1993	36[a]

a. Drainage is for Jan. 1 through Aug.31.

In 1989, selected sediment samples from the SDA were analyzed for hydrological and physical properties (McElroy and Hubbell, 1990). The analysis included two samples taken from borehole W06, located approximately 4 ft east of NAT W06. The samples were collected during the summer of 1986 and archived until 1989 when they were submitted for analysis. Measurements were performed for the following:

- Hydraulic conductivity
- Moisture-retention characteristics
- Moisture content
- Bulk density
- Porosity
- Particle density
- Particle-size distribution
- Unsaturated hydraulic conductivity
- Air permeability.

The majority of the testing was performed by a private laboratory. However, one of the W06 samples was analyzed by the INEL laboratory for saturated hydraulic conductivity.

The W06 samples were taken from two depth ranges. The first was taken from a core section located 52 to 82 cm below the surface. The second was taken from a core section located 335 to 360 cm below the surface. Because the samples were taken from a known general depth, the opportunity presented itself to compare the laboratory hydraulic properties with the calibrated properties from the NAT simulation. Laboratory properties are compared to the calibrated properties in Tables 3.1.5-7 and 3.1.5-8. Because the archived core sections extended through more than one layer of the simulation profile, properties are presented for depth ranges rather than specific depths.

Results of the comparison show that the calibrated hydraulic parameters agree well with the laboratory parameters. This was expected because the laboratory parameters were used as the initial estimates in the model. The calibrated parameters were within the 95% confidence limits of the laboratory parameters with the exception of α and K_S. To match the field tension measurements, it was necessary to significantly increase α. Increasing α had the effect of decreasing the air entry potential and lowering the soil moisture curve. It was necessary to increase the K_S values to match the travel times of the wetting front created by the spring snowmelt. The calibrated K_S was an order of magnitude higher than the values determined by the private lab. However, the calibrated K_S was also an order of magnitude lower than the value determined by the INEL lab.

One reason for the discrepancies between the lab estimates and the calibration estimates of hydraulic properties is that significant spatial variations may be occurring over small distances in the SDA sediments. Laboratory analysis of different samples taken from the same relatively short core sections resulted in significantly different parameter estimates for some cases. Furthermore, the depth range from which the two core sections were extracted extended through several of the simulation layers. For these reasons, the limited data from the laboratory analysis should be viewed with discretion because it may represent only a small portion of the surficial sediments.

Table 3.1.5-7. Laboratory scale hydraulic properties (Table 9 from Martian and Magnuson, 1994).

Depth range (cm)	K_S (cm/hr)	INEL Lab. K_S	α (1/cm)	Lower 95%	Upper 95%	n	Lower	Upper	θ_s	θ_r	Variation (approx.)
52–82	0.61	36.0	0.0012	0.0044	0.0195	1.5891	1.3293	1.8489	0.511	0.126	12
335–360	0.21	—	0.0071	0.0041	0.0100	1.5756	1.4017	1.7498	0.496	0.142	14

Table 3.1.5-8. Simulation hydraulic properties (Table 10 from Martian and Magnuson, 1994).

Depth range (cm)	K_S (cm/hr)	α (1/cm)	n	θ_s	θ_r	Variation (approx.)
43–57	8.20	0.0139	1.725	0.527	0.089	3
57–70	6.60	0.0131	1.687	0.514	0.115	4
70–100	5.00	0.0123	1.650	0.500	0.140	5
230–320	5.00	0.0123	1.650	0.500	0.140	11

The frequent monitoring of NAT W06 during the 1993 spring snowmelt infiltration event provided sufficient data to perform field scale estimation of hydraulic properties. McElroy (unpublished work, 1994) used the soil moisture and matric potential data during drainage periods to estimate hydraulic parameters for a characteristic curve and an unsaturated conductivity curve at different depths. Estimates for K_s, θ_s, θ_r, and n were obtained using the UNGRA computer code (van Genuchten, 1988) at 1/2-ft intervals, while estimates for K_s, θ_s, θ_r, n, and α at 3-ft and 6-ft depths were determined using the RETC computer code (van Genuchten, 1985). Results of the field scale investigation in Table 3.1.5-9 can be compared to the simulation results in Table 3.1.5-10.

Results from the comparison indicate that the calibrated K_s values in the low conductivity zones tend to be an order of magnitude higher while the high conductivity zones values are comparable. Field estimates of porosity are lower than the calibration estimates. Values of 0.40 vs. 0.50 were obtained for the calibration and field estimates, respectively. Estimates for residual moisture contents in most of the relatively high conductivity zones were zero, suggesting that the very low pressure section of the soil moisture curve determined from the field parameters may not be valid. Field estimates for α at the 3- and 6-ft depths were lower and higher, respectively, than the calibration estimates. Finally, field estimates for the n parameter tended to be lower than the calibration estimates, especially in the higher conductivity regions. A significant amount of variation was seen in the field estimates, which can be seen in the large spread between the 95% confidence intervals. As can be seen in Table 3.1.5-9, many of the intervals ranged to below zero, which physically should not occur.

Table 3.1.5-9. Field scale hydraulic properties (Table 11 from Martian and Magnuson, 1994).

Depth (cm)	K_S (cm/hr)	Lower 95%	Upper 95%	θ_S	Lower	Upper	θ_r	Lower	Upper	α (1/cm)	Lower	Upper	n	Lower	Upper
30.5	0.81	-4.42	6.04	.441	.316	.566	.000			.0300 /a			1.235	1.040	1.420
45.7	0.02	-0.01	0.05	.386	.376	.397	.000			.0055 /a			1.535	.9217	2.148
61.0	0.02	-0.01	0.05	.386	.376	.397	.000			.0055 /a			1.535	.9217	2.148
76.2	1.20	-105	107.	.394	.382	.406	.171	-9.10	9.44	.0500 /a			1.134	-5.800	8.067
91.4	0.15	-0.20	0.51	.382	.376	.388	.000			.0055	-0.0009	0.1200	1.158	1.037	1.285
107.	2.66	-27.4	32.7	.391	.304	.477	.000			.0220 /a			1.124	.9122	1.335
122.	3.26	-37.7	44.2	.376	.262	.491	.000			.0385 /a			1.141	.8909	1.391
137.	0.06	-0.29	0.41	.364	.302	.425	.221	-.234	.675	.0551 /a			2.378	-7.478	12.35
167.	2.42	-13.7	18.5	.403	.309	.496	.000			.0551 /a			1.220	.9971	1.443
183.	45.5	-208	299.	.524	.335	.711	.000			.1046	-0.1462	0.3554	1.233	1.168	1.298
213.	0.04	0.01	0.07	.347	.259	.319	.283	.259	.319	.0055 /a			18.73	-132.2	169.6
229.	3.92	-74.7	82.6	.368	.226	.511	.000			.0055 /a			1.131	.7026	1.559
244.	11.9	-95.9	119.	.402	.296	.508	.000			.0055 /a			1.141	1.002	1.281

/a Estimated through limited calibration.

Table 3.1.5-10. Simulation hydraulic properties (Table 10 from Martian and Magnuson, 1994).

Depth (cm)	K_S (cm/hr)	θ_S	θ_r	α (1/cm)	n	Soil layer description
30–43	9.8	.540	.064	.0147	1.763	Transition
43–57	8.2	.527	.089	.0139	1.725	Transition
57–70	6.6	.514	.115	.0131	1.688	Transition
70–100	5.0	.500	.140	.0123	1.650	Silt
100–110	7.5	.503	.133	.0169	1.630	Transition
110–120	10.0	.507	.127	.0216	1.610	Transition
120–190	12.5	.510	.120	.0262	1.590	Sandy Silt
190–210	10.0	.507	.127	.0216	1.610	Transition
210–230	7.5	.503	.133	.0169	1.630	Transition
230–320	5.0	.500	.140	.0123	1.650	Silt

3.2 Sedimentary Interbeds Hydrogeologic Properties

3.2.1 Summary of Data from EG&G Idaho, Inc. Studies - Sedimentary Interbeds

Results of hydrogeologic properties of the sedimentary interbeds were compiled from several sources. The studies from which the data were compiled are discussed to provide information about the condition and analyses of the samples. The studies were generally limited to undisturbed areas of the SDA because of the safety problems inherent in sampling through the waste pits.

Sedimentary interbed cores were collected by Barraclough et al. (1976) (see Section 3.2.3) as part of a hydrogeologic investigation of the RWMC. Sedimentary cores from wells within the SDA (Wells 91 through 96) were generally collected using a Shelby-type split-spoon, rotary drive-core technique. A 2-in. (50 mm) ID core was collected in a steel liner. This drive-core sampler was not always effective in coarser-grained unconsolidated sediments. In such cases, the sediments were loosened and blown to the surface using a standard rotary tricone bit with air circulation. The loosened sediments were collected at the surface. A third technique was employed for some sediment samples from Well 96. A sampler was fabricated that was twisted into the sediments but not allow the sediments to drop out as easily as they did in the drive-core sampler. This sampler physically disturbed the core more than the drive-core technique.

Sedimentary cores from wells outside the SDA (Wells 87 through 90) were collected using split-spoon, drive-core sampling tools. Sediment core samples were 4 in. (100 mm) in diameter and were contained in an inner aluminum liner. This type of sampling often failed with dry, unconsolidated sands and gravels.

Retrieved sediment samples were sealed at both ends with wax to prevent loss of moisture and minimize physical disturbance. Selected cores were analyzed for particle-size distribution, saturated hydraulic conductivity, particle density, bulk density, porosity, and moisture content (gravimetric) at the USGS Laboratory in Denver, Colorado. The analytical procedures and results are described in Barraclough et al. (1976).

McElroy and Hubbell (1990) (see Section 3.3) present hydrogeologic data that includes the properties listed in Barraclough et al. (1976), with the addition of moisture-release curves and unsaturated hydraulic conductivity. The samples for this study were collected by air-rotary, wire-line coring techniques. Samples were sealed before storage. Analyses were performed using standard ASTM procedures, whenever possible, and those procedures are described in McElroy and Hubbell (1990). The interbed samples were stored for periods ranging from one to three years before analyses. The long storage probably affected the saturated and unsaturated hydraulic conductivity, moisture-release curve, moisture content, and porosity results. However, this data is valuable because of the derth of similar data from undisturbed interbed core.

Samples of sedimentary material from Boreholes 93A and 96B at the RWMC were analyzed for particle-size distribution (Rightmire, 1984). The procedures used for particle-size distribution are identical to those referenced in Barraclough et al. (1976). Sediment core was collected into 2-ft barrels lined with a plastic sleeve, using rotary (without air) coring. The plastic sleeve was capped and sealed directly after withdrawal from the borehole. Drive-core techniques were used for a few cores, such as in sediment with a high clay content. This technique also incorporated a plastic sleeve to contain the core.

The results of analyses of hydrogeologic properties of the interbed sediments from the above mentioned studies are presented in Tables 3.2.1-1a, b, c, and d and 3.2.1-2a, b, c, and d. These properties include grain-size distribution, particle density, bulk density, porosity, moisture content, and vertical hydraulic conductivity. Moisture release curves and unsaturated hydraulic conductivities are presented in Appendix A of McElroy and Hubbell, 1990.

Table 3.2.1-3 lists the ranges, arithmetic means, and standard deviations about the means of particle-size medians, initial moisture contents, and vertical hydraulic conductivities using data from Tables 3.2.1-1 and 3.2.1-2. The mean particle-size was calculated by averaging the particle-size medians (d50) for each sample within the designated interbed. Means for moisture content and vertical hydraulic conductivity were calculated by arithmetically averaging the reported values within each interbed.

Table 3.2.1-1a. Particle-size distribution for the 30-ft sedimentary interbed, presenting the precent weight in each size category.

Sample Number	Well Number	Depth Interval Top (ft)	Depth Interval bottom (ft)	Particle-size Distribution %Clay (mm) <0.004	%Silt (mm) 0.004-0.062	% Sand (mm) .062-.125	.125-.250	.250-.500	.500-1.00	1.00-2.00	2.00-4.00	4.00-8.00	% Gravel (mm) 8.00-16.0	16.0-32.0	32.0-64.0	Statistical Parameters Coefficient of Uniformity	Median	Sorting Coefficient	Coefficient of Skewness	Kurtosis	Reference[a]
	BG-91	26.00	32.0	32.2	64.8	.5	2.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	140.0	9.8×10^{-3}	3.8	0.45	----	BA76
1	96B	35.60	----	7.9	31.6	6.2	5.4	5.9	8.4	1.5	2.8	7.1	16.9	6.3	0.0	17.0	0.22	18.0	3.00	0.24	RI84
2	96B	38.70	----	8.7	46.8	18.3	14.8	11.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	6.2	0.05	2.8	1.00	0.21	RI84
3	96B	39.90	----	4.0	11.1	26.1	38.0	18.7	2.3	0.0	0.0	0.0	0.0	0.0	0.0	7.5	0.15	1.7	0.86	0.21	RI84
4	96B	40.30	----	4.1	17.9	26.2	36.8	13.3	1.2	0.1	0.0	0.0	0.0	0.0	0.0	-----	0.13	1.8	0.87	0.23	RI84

Sample Number	Well Number	Depth Interval Top (ft)	Depth Interval bottom (ft)	Particle-size Distribution %Clay (mm) <0.005	%Silt (mm) 0.005-0.075	% Sand (mm) 0.075-0.106	0.106-0.212	0.012-0.425	0.425-1.18	1.18-2.0	% Gravel (mm) 2.0-3.35	3.35-4.75	>4.75	Statistical Parameters Coefficient of Uniformity	Median	Sorting Coefficient	Coefficient of Skewness	Kurtosis	Reference[a]
D89	D10	31.50	34.7	4.74	58.82	12.81	14.23	8.12	1.21	0.02	0.00	0.00	0.00	6.4	0.055				MC90
D90	D10	34.70	36.0	7.02	42.91	29.54	19.20	1.23	0.07	0.01	0.02	0.00	0.00	11.0	0.075				
D90XH-2	D10	34.70	36.0	5.63	42.04	39.03	12.16	1.05	0.09	0.00	0.00	0.00	0.00	9.1	0.076				

Source:
BA76: Barraclough et al. (1976)
RI84: Rightmire (1984)
MC90: McElroy and Hubbell (1990)

Table 3.2.1-1b. Particle-size distribution for the 110-ft sedimentary interbed, presenting the precent weight in each size category.

Sample Number	Well Number	Depth Interval Top (ft)	Depth Interval bottom (ft)	Particle-size Distribution %Clay (mm) <0.004	%Silt (mm) 0.004-0.062	% Sand (mm) .062-.125	.125-.250	.250-.500	.500-1.00	1.00-2.00	% Gravel (mm) 2.00-4.00	4.00-8.00	8.00-16.0	16.0-32.0	32.0-64.0	Statistical Parameters Coefficient of Uniformity	Median	Sorting Coefficient	Coefficient of Skewness	Kurtosis	Reference[a]
	BG-88	108.50	111.0	8.0	31.8	10.5	14.4	12.9	12.9	2.4	4.6	2.5	0.0	0.0	0.0	46.0	0.12	4.5	0.620	0.210	BA76
	BG-88	112.50	113.5	6.6	34.0	11.1	14.7	12.9	10.7	3.6	4.3	2.1	0.0	0.0	0.0	37.0	0.11	4.5	0.610	0.190	BA76
	BG-91	74.00	92.0	34.5	38.7	0.2	2.3	1.6	2.8	2.6	3.7	2.2	11.4	0.0	0.0	-----	1.5×10^{-2}	11.0	1.600	-----	BA76
	BG-91	105.00	107.0	44.8	47.9	0.5	2.7	1.2	1.0	0.2	0.6	1.2	0.0	0.0	0.0	-----	5.8×10^{-3}	4.0	1.500	-----	BA76
	BG-93	88.30	90.3	19.1	65.5	0.4	6.2	1.1	0.4	0.0	0.2	0.2	0.0	6.8	0.1	25.0	2.1×10^{-2}	3.0	0.570	0.100	BA76
	BG-93	103.00	105.0	14.9	41.3	0.2	11.2	7.8	10.4	5.5	3.3	3.3	2.2	0.0	0.0	140.0	5.0×10^{-2}	6.4	2.400	0.140	BA76
	BG-93	105.00	110.0	16.3	30.6	7.4	11.0	11.0	10.8	3.4	3.2	3.0	3.3	0.0	0.0	-----	8.3×10^{-2}	6.5	0.720	-----	BA76
	BG-94	110.00	112.0	5.1	13.4	13.9	20.7	15.5	11.2	5.1	5.3	5.5	4.2	0.0	0.0	23.0	0.22	2.9	1.300	0.085	BA76
	BG-95	106.00	107.0	24.2	18.2	8.5	17.4	24.6	6.9	0.2	0.0	0.0	0.0	0.0	0.0	-----	0.12	8.3	0.098	0.190	BA76
	BG-95	109.50	112.0	36.1	28.0	16.5	12.0	4.7	2.4	0.4	0.0	0.0	0.0	0.0	0.0	-----	2.3×10^{-2}	4.8	0.790	-----	BA76
	BG-96	101.90	103.0	- 0.8	-	0.8	5.3	16.4	25.6	13.6	25.0	12.4	0.0	0.0	0.0	61.0	1.10	2.3	1.300	0.270	BA76
	BG-96	116.60	119.1	52.4	37.7	3.0	6.0	0.2	0.8	0.0	0.0	0.0	0.0	0.0	0.0	-----	5.3×10^{-4}	3.9	0.470	-----	BA76
93A-15	93A	100.47	-----	15.7	18.0	6.1	10.8	16.8	12.4	6.4	5.4	4.6	3.8	0.0	0.0	-----	0.24	6.0	0.300	-----	RI84
93A-16	93A	102.17	-----	12.7	12.4	4.8	6.4	8.9	15.9	10.5	12.5	11.7	4.1	0.0	0.0	-----	0.65	6.4	0.370	-----	RI84
93A-17	93A	103.19	-----	17.5	16.0	5.9	8.1	11.5	9.6	8.1	9.8	7.7	5.6	0.0	0.0	-----	0.30	11.0	0.280	-----	RI84
93A-18	93A	103.19	(Cavings)	0.8	0.8	5.4	8.0	23.7	8.6	2.9	0.2	4.2	15.2	30.9	0.0	-----	4.30	7.2	0.370	0.610	RI84
93A-19	93A	106.17	-----	13.9	19.7	6.3	13.0	10.4	7.9	3.8	8.6	7.1	5.2	4.1	0.0	-----	0.22	8.7	1.100	-----	RI84
93A-20	93A	108.17	-----	11.1	5.1	3.6	8.0	10.7	4.8	4.4	20.4	18.0	13.8	0.0	0.0	1229.0	2.20	5.2	0.230	0.260	RI84
93A-21	93A	109.06	-----	7.7	48.9	8.0	6.5	3.1	4.3	3.6	11.3	3.6	3.1	0.0	0.0	22.0	0.04	10.0	2.700	0.260	RI84
93B-6	96B	101.48	-----	3.6	4.9	2.4	3.1	4.5	11.6	6.8	12.4	16.7	28.1	5.9	0.0	65.0	4.20	4.6	0.300	0.340	RI84
96B-7	96B	116.47	-----	72.0	8.7	6.4	7.1	3.2	1.2	1.5	0.0	0.0	0.0	0.0	0.0	-----	----------	----	-----	-----	RI84
96B-8	96B	122.48	-----	1.2	1.2	19.4	66.6	12.6	0.1	0.2	0.0	0.0	0.0	0.0	0.0	2.2	0.18	1.3	0.930	0.220	RI84
96B-9	96B	127.17	-----	7.7	10.8	20.9	27.5	23.9	6.5	0.5	0.1	0.6	1.5	0.0	0.0	32.0	0.17	2.0	0.910	0.260	RI84

Sample Number	Well Number	Depth Interval Top (ft)	Depth Interval bottom (ft)	Particle-size Distribution %Clay (mm) <0.005	%Silt (mm) 0.005-0.075	% Sand (mm) 0.075-0.106	0.106-0.212	0.012-0.425	0.425-1.18	1.18-2.0	% Gravel (mm) 2.0-3.35	3.35-4.75	>4.75	Statistical Parameters Coefficient of Uniformity	Median	Sorting Coefficient	Coefficient of Skewness	Kurtosis	Reference[a]
D67	D15	108.6	111.0	- 12.2	-	18.35	44.08	24.25	1.10	0.00	0.00	0.00	0.00	-	0.16				

Source:
BA76: Barraclough et al. (1976)
RI84: Rightmire (1984)
MC90: McElroy and Hubbell (1990)

Table 3.2.1-1c. Particle-size distribution for the 240-ft sedimentary interbed, presenting the precent weight in each size category.

Sample Number	Well Number	Depth Interval Top (ft)	Depth Interval bottom (ft)	%Clay (mm) <0.004	%Silt (mm) 0.004-0.062	% Sand (mm) .062-.125	% Sand (mm) .125-.250	% Sand (mm) .250-.500	% Sand (mm) .500-1.00	% Sand (mm) 1.00-2.00	% Gravel (mm) 2.00-4.00	% Gravel (mm) 4.00-8.00	% Gravel (mm) 8.00-16.0	% Gravel (mm) 16.0-32.0	% Gravel (mm) 32.0-64.0	Coefficient of Uniformity	Median	Sorting Coefficient	Coefficient of Skewness	Kurtosis	Reference[a]
				Particle-size Distribution												Statistical Parameters					
	BG-87	236.00	237.5	10.1	57.1	0.0	8.7	0.7	5.1	7.3	4.7	2.8	3.5	0.0	0.0	14.0	3.8 x 10 -2	4.80	1.50	0.0480	BA76
	BG-87	242.00	243.5	5.0	34.0	0.2	17.0	12.7	10.5	9.9	5.2	3.8	1.8	0.0	0.0	33.0	0.190	4.60	0.69	0.1600	BA76
	BG-88	237.00	238.2	16.0	80.0	2.3	1.0	0.4	0.2	0.2	0.0	0.0	0.0	0.0	0.0	12.0	1.6 x 10 -2	2.50	0.84	0.3000	BA76
	BG-88	247.50	249.0	40.9	53.5	1.4	3.2	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-----	4.6 x 10 -3	2.80	0.65	-----	BA76
	BG-88	265.50	267.0	37.9	61.1	0.2	0.6	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	-----	6.3 x 10 -3	3.50	0.68	-----	BA76
	BG-89	241.00	241.7	23.3	63.3	6.7	5.3	0.6	0.8	0.0	0.0	0.0	0.0	0.0	0.0	-----	1.0 x 10 -2	2.90	1.10	-----	BA76
	BG-89	243.50	245.5	38.3	54.6	0.0	6.5	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-----	6.9 x 10 -3	4.60	1.30	-----	BA76
	BG-89	250.80	252.2	7.0	58.3	1.2	14.2	3.4	4.1	1.8	3.5	4.8	1.7	0.0	0.0	8.1	4.4 x 10 -2	3.10	1.90	0.0420	BA76
	BG-89	249.00	250.0	8.5	57.9	12.5	14.6	1.3	1.3	0.0	2.4	1.5	0.0	0.0	0.0	12.0	3.8 x 10 -2	2.70	1.00	0.2100	BA76
	BG-90	250.00	251.5	10.4	43.1	7.4	14.3	0.7	0.9	0.9	0.9	3.2	11.1	7.3	0.0	33.0	5.4 x 10 -2	3.80	1.50	0.0086	BA76
	BG-91	233.80	236.3	5.8	13.6	11.6	40.6	22.6	4.3	0.4	1.1	0.1	0.0	0.0	0.0	24.0	0.170	1.80	0.81	0.2200	BA76
	BG-91	236.30	238.8	9.8	75.6	13.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7	2.0 x 10 -2	2.40	0.90	0.2400	BA76
	BG-91	243.20	245.1	23.1	55.7	9.2	11.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-----	1.9 x 10 -2	3.50	0.67	-----	BA76
	BG-92	225.50	228.0	10.0	77.6	10.4	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.0	3.7 x 10 -2	1.80	0.60	0.2600	BA76
	BG-92	233.50	236.0	17.8	33.2	10.6	20.6	13.8	4.0	0.0	0.0	0.0	0.0	0.0	0.0	-----	5.8 x 10 -2	5.10	0.44	-----	BA76
	BG-92	244.60	246.2	24.0	74.6	0.8	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-----	4.7 x 10 -3	4.30	0.74	-----	BA76
	BG-93	228.80	229.8	14.2	33.9	4.5	11.1	22.1	11.7	2.5	0.0	0.0	0.0	0.0	0.0	100.0	8.3 x 10 -2	4.50	0.89	0.2700	BA76
	BG-94	228.90	231.3	15.6	60.3	12.4	5.7	5.9	0.2	0.0	0.0	0.0	0.0	0.0	0.0	22.0	2.4 x 10 -2	2.60	0.93	0.1700	BA76
	BG-94	236.30	239.8	17.5	49.5	8.8	11.8	9.8	2.6	0.0	0.0	0.0	0.0	0.0	0.0	-----	1.9 x 10 -2	6.90	0.81	-----	BA76
	BG-94	244.80	247.8	23.6	64.4	4.8	1.7	0.2	0.4	0.0	1.1	1.4	2.4	0.0	0.0	-----	1.3 x 10 -2	2.70	0.63	-----	BA76
	BG-94	270.30	272.3	27.5	56.5	2.3	0.6	0.2	0.0	0.0	0.7	0.9	0.0	11.3	0.0	-----	1.3 x 10 -2	3.80	0.67	-----	BA76
	BG-95	229.30	231.8	7.1	72.7	11.6	8.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.0	1.5 x 10 -2	3.30	1.00	0.2000	BA76
	BG-95	231.80	233.3	22.0	70.6	4.4	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-----	5.6 x 10 -3	4.80	0.78	-----	BA76
	BG-96	224.10	227.6	30.0	62.6	6.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-----	1.5 x 10 -2	3.90	0.47	-----	BA76
93A-26	93A	226.45	-----	18.2	13.4	2.9	5.2	9.1	26.0	25.1	0.0	0.0	0.0	0.0	0.0	518.0	0.520	6.90	0.80	0.3100	RI84
93A-27	93A	227.83	-----	45.1	24.2	6.8	12.0	11.9	0.0	0.1	0.0	0.0	0.0	0.0	0.0	-----	0.010	9.50	5.20	-----	RI84
93A-28	93A	229.24	-----	13.8	42.8	9.1	6.5	7.3	5.2	3.0	8.0	3.3	0.9	0.0	0.0	34.0	0.050	4.20	2.50	0.0600	RI84
93A-29	93A	231.63	-----	26.8	47.1	6.7	8.1	6.5	2.7	0.1	1.1	0.9	0.0	0.0	0.0	-----	0.020	5.00	0.52	-----	RI84
93A-30	93A	233.14	-----	23.3	43.0	7.5	7.8	6.9	4.8	3.8	0.5	2.0	0.4	0.0	0.0	-----	0.019	6.00	1.50	-----	RI84
96B-14	96B	213.56	-----	9.8	1.5	1.6	2.0	3.7	6.5	13.0	22.1	25.9	13.97	0.0	0.0	251.0	2.900	2.50	0.70	0.2600	RI84
96B-15	96B	221.24	-----	6.9	40.9	26.3	15.2	9.8	0.8	0.0	0.0	0.0	0.0	0.0	0.0	7.6	0.066	2.40	0.68	0.2100	RI84
96B-16	96B	224.75	-----	8.8	43.2	40.8	5.6	0.9	0.5	0.1	0.0	0.0	0.0	0.0	0.0	17.0	0.060	1.90	0.67	0.2900	RI84
96B-17	96B	229.63	-----	10.0	68.1	17.6	3.3	0.8	0.1	0.0	0.0	0.0	0.0	0.0	0.0	-----	-----	0.26	3.00	0.5700	RI84

Sample Number	Well Number	Depth Interval Top (ft)	Depth Interval bottom (ft)	%Clay (mm) <0.005	%Silt (mm) 0.005-0.075	% Sand (mm) 0.075-0.106	% Sand (mm) 0.106-0.212	% Sand (mm) 0.012-0.425	% Sand (mm) 0.425-1.18	% Sand (mm) 1.18-2.0	% Gravel (mm) 2.0-3.35	% Gravel (mm) 3.35-4.75	% Gravel (mm) >4.75	Coefficient of Uniformity	Median	Sorting Coefficient	Coefficient of Skewness	Kurtosis	Reference[a]
				Particle-size Distribution										Statistical Parameters					
D36	D02	232.60	234.2	-4.43	-	4.71	36.42	36.53	16.82	0.95	0.09	0.05	0.00	2.5	0.220				MC90
D37	D02	234.20	235.2	- 6.07	-	6.37	32.46	35.21	18.01	1.62	0.11	0.15	0.00	3.2	0.230				MC90
D35	D02	230.30	232.6	7.28	24.85	19.62	23.63	18.32	6.02	0.18	0.10	0.00	0.00	16.3	0.100				MC90
D77B	D15	229.40	233.4	22.25	39.70	12.95	23.28	1.72	0.09	0.01	0.00	0.00	0.00	----	0.020				MC90
D79A	D15	237.30	239.3	21.96	53.52	15.19	9.32	0.00	0.00	0.01	0.00	0.00	0.00	8.6	0.013				MC90
D49	8801D	230.10	233.3	22.00	57.44	9.07	7.63	3.54	0.32	0.00	0.00	0.00	0.00	8.3	0.012				MC90
D49XH-2	8801D	230.10	233.3	19.92	58.76	11.84	7.91	1.47	0.09	0.01	0.00	0.00	0.00	7.8	0.013				MC90
D50	8801D	233.30	235.4	21.65	41.55	18.66	14.05	3.89	0.20	0.00	0.00	0.00	0.00	50.7	0.020				MC90
D52	8801D	240.00	242.1	9.89	6.85	41.92	29.57	11.36	0.39	0.02	0.00	0.00	0.00	21.8	0.098				MC90
D001	118	225.00	230.0	7.47	29.70	25.05	29.31	8.07	0.39	0.01	0.00	0.00	0.00	14.3	0.090				MC90
D002	118	240.00	244.0	25.47	20.51	20.44	24.33	8.61	0.64	0.00	0.00	0.00	0.00	86.4	0.080				MC90

Source:
BA76: Barraclough et al. (1976)
RI84: Rightmire (1984)
MC90: McElroy and Hubbell (1990)

Table 3.2.1-1d. Particle-size distribution for sedimentary interbeds below the 240-ft interbed, presenting the precent weight in each size category.

		Depth Interval		Particle-size Distribution												Statistical Parameters					
				%Clay (mm)	%Silt (mm)	% Sand (mm)					% Gravel (mm)										
Sample Number	Well Number	Top (ft)	bottom (ft)	<0.004	0.004-0.062	.062-.125	.125-.250	.250-.500	.500-1.00	1.00-2.00	2.00-4.00	4.00-8.00	8.00-16.0	16.0-32.0	32.0-64.0	Coefficient of Uniformity	Median	Sorting Coefficient	Coefficient of Skewness	Kurtosis	Reference[a]
	BG-87	559.00	561.0	9.20	55.10	14.8	12.6	0.2	0.6	0.0	0.7	2.1	4.8	0.0	0.0	12.0	3.7 x 10 -2	2.5	1.2	0.190	BA76
	BG-88	519.00	521.0	7.30	57.00	0.4	21.2	2.4	1.8	0.4	3.9	3.6	2.1	0.0	0.0	6.8	5.0 x 10 -2	2.3	2.3	0.073	BA76

		Depth Interval		Particle-size Distribution										Statistical Parameters					
				%Clay (mm)	%Silt (mm)	% Sand (mm)					% Gravel (mm)								
Sample Number	Well Number	Top (ft)	bottom (ft)	<0.005	0.005-0.075	0.075-0.106	0.106-0.212	0.012-0.425	0.425-1.18	1.18-2.0	2.0-3.35	3.35-4.75	>4.75	Coefficient of Uniformity	Median	Sorting Coefficient	Coefficient of Skewness	Kurtosis	Reference[a]
D004	118	569.00	572.0	28.87	43.33	27.76	-	-	-	-	-	-	-	-	0.018				MC90

Source:
BA76: Barraclough et al. (1976)
RI84: Rightmire (1984)
MC90: McElroy and Hubbell (1990)

Table 3.2.1-2a. Hydrogeologic properties core from the 30 -ft sedimentary interbed.

Sample Number	Borehole Number	Depth Interval Top (ft)	Depth Interval Bottom (ft)	Particle Density (g/cc)	Bulk Density (g/cc)	Porosity %	Moisture Content (%, g/g)	Saturated Moisture Content (%, g/cc)	Vertical Hydraulic Conductivity (cm/s)	Reference[a]
	BG-91	26.00	32.0	2.64	1.90	38.80	27.50	-	1.51×10^{-5}	BA76
96B-1	96B	35.59	-	2.66	-	-	-	-	-	RI84
96B-2	96B	38.38	-	2.71	-	-	-	-	-	RI84
96B-3	96B	39.66	-	2.69	-	-	-	-	-	RI84
96B-4	96B	40.28	-	2.66	-	-	-	-	-	RI84
D89	D10	31.50	34.7	2.71	1.23	54.43	20.16	55.40	5.06×10^{-3}	MC90
D90	D10	34.70	36.0	2.63	1.18	55.06	27.35	62.22	3.98×10^{-4}	MC90
D90XH-2	D10	34.70	36.0	2.63	1.29	48.99	39.60	61.51	9.00×10^{-6}	MC90

Source:
BA76: Barraclough et al. (1976)
RI84: Rightmire (1984)
MC90: McElroy and Hubbell (1990)

Table 3.2.1-2b. Hydrogeologic properties core from the 110 -ft sedimentary interbed.

Sample Number	Borehole Number	Depth Interval Top (ft)	Depth Interval Bottom (ft)	Particle Density (g/cc)	Bulk Density (g/cc)	Porosity %	Moisture Content (%, g/g)	Saturated Moisture Content (%, g/cc)	Vertical Hydraulic Conductivity (cm/s)	Reference[a]
-	BG-88	108.50	111.0	3.03	2.41	28.10	23.20	-	-	BA76
-	BG-88	112.50	113.5	3.02	2.34	30.10	23.00	-	-	BA76
-	BG-91	74.00	92.0	2.66	1.90	35.50	19.30	-	3.47 x 10 -3	BA76
-	BG-91	105.00	107.0	2.67	-	-	-	-	-	BA76
-	BG-93	103.00	105.0	2.86	-	-	-	-	-	BA76
-	BG-93	105.00	110.0	2.87	-	-	-	-	-	BA76
-	BG-94	110.00	112.5	2.67	1.85	36.50	15.10	-	8.79 x 10 -4	BA76
-	BG-95	106.00	107.0	2.66	1.62	44.70	15.40	-	1.74 x 10 -4	BA76
-	BG-95	109.50	112.0	2.67	2.30	20.60	17.80	-	3.59 x 10 -9	BA76
-	BG-96	116.60	119.1	2.64	1.87	43.20	37.20	-	7.64 x 10 -9	BA76
93A-15	93A	100.47	-	2.68	-	-	-	-	-	RI84
93A-16	93A	102.17	-	2.72	-	-	-	-	-	RI84
93A-17	93A	103.19	-	2.68	-	-	-	-	-	RI84
93A-19	93A	106.17	-	2.67	-	-	-	-	-	RI84
93A-20	93A	108.17	-	2.76	-	-	-	-	-	RI84
93A-21	93A	109.06	-	2.68	-	-	-	-	-	RI84
96B-6	96B	101.48	-	2.77	-	-	-	-	-	RI84
96B-7	96B	116.47	-	2.60	-	-	-	-	-	RI84
96B-9	96B	127.17	-	2.70	-	-	-	-	-	RI84
D67	D15	108.60	111.0	2.59	1.61	37.90	26.00	47.24	1.13 x 10 -8	MC90

Source:
BA76: Barraclough et al. (1976)
RI84: Rightmire (1984)
MC90: McElroy and Hubbell (1990)

Table 3.2.1-2c. Hydrogeologic properties core from the 240 -ft sedimentary interbed.

Sample Number	Borehole Number	Depth Interval Top (ft)	Depth Interval Bottom (ft)	Particle Density (g/cc)	Bulk Density (g/cc)	Porosity %	Moisture Content (%, g/g)	Saturated Moisture Content (%, g/cc)	Vertical Hydraulic Conductivity (cm/s)	Reference[a]
	BG-87	236.00	237.5	2.73	2.33	35.70	37.70	-	2.89×10^{-5}	BA76
	BG-87	242.00	243.5	2.56	1.87	42.70	40.20	-	3.70×10^{-7}	BA76
	BG-88	237.00	238.5	2.78	1.95	46.30	45.70	-	1.51×10^{-4}	BA76
	BG-88	247.50	249.0	2.64	1.91	42.10	38.40	-	4.05×10^{-8}	BA76
	BG-88	253.50	255.0	-	-	-	-	-	9.14×10^{-10}	BA76
	BG-88	265.50	267.0	2.64	2.15	35.00	42.70	-	3.59×10^{-9}	BA76
	BG-89	241.00	241.7	2.70	2.07	35.60	33.00	-	1.85×10^{-10}	BA76
	BG-89	243.50	245.5	2.66	1.95	38.10	29.60	-	7.06×10^{-8}	BA76
	BG-89	250.80	252.2	2.71	2.20	28.50	26.10	-	6.71×10^{-8}	BA76
	BG-90	249.00	250.0	2.76	1.80	46.10	30.60	-	3.36×10^{-5}	BA76
	BG-90	250.00	251.5	2.64	1.70	53.30	-	-	-	BA76
	BG-91	233.80	236.3	2.68	1.34	53.40	9.10	-	8.33×10^{-4}	BA76
	BG-91	236.30	238.8	2.74	1.56	50.40	-	-	3.00×10^{-4}	BA76
	BG-91	243.20	245.1	2.64	2.06	50.30	21.80	-	-	BA76
	BG-92	225.50	228.0	2.66	1.58	45.10	11.70	-	3.01×10^{-3}	BA76
	BG-92	233.50	236.0	2.71	1.87	37.60	18.10	-	3.13×10^{-5}	BA76
	BG-92	244.60	246.2	2.65	2.06	35.10	34.10	-	2.43×10^{-9}	BA76
	BG-93	228.80	229.8	2.75	1.73	42.20	14.40	-	6.37×10^{-5}	BA76
	BG-94	228.80	231.3	2.68	1.86	40.80	27.30	-	1.85×10^{-5}	BA76
	BG-94	236.30	238.8	2.72	1.73	41.10	13.40	-	2.66×10^{-4}	BA76
	BG-94	244.80	247.8	2.67	2.11	33.90	35.40	-	8.33×10^{-8}	BA76
	BG-94	270.30	272.3	2.60	-	-	-	-	6.48×10^{-8}	BA76
	BG-95	229.30	231.8	2.68	1.70	46.30	26.40	-	3.24×10^{-4}	BA76
	BG-95	231.80	233.3	2.68	1.83	42.50	29.00	-	1.08×10^{-3}	BA76
	BG-96	224.10	226.6	2.67	1.96	37.10	27.60	-	2.19×10^{-6}	BA76
93A-26	93A	226.45	-	2.79	-	-	-	-	-	RI84
93A-27	93A	227.83	-	2.85	-	-	-	-	-	RI84
93A-28	93A	229.24	-	2.69	-	-	-	-	-	RI84
93A-29	93A	231.83	-	2.76	-	-	-	-	-	RI84
93A-30	93A	233.14	-	2.84	-	-	-	-	-	RI84
96B-14	96B	213.53	-	2.99	-	-	-	-	-	RI84
96B-15	96B	221.24	-	2.68	-	-	-	-	-	RI84
96B-16	96B	224.75	-	2.71	-	-	-	-	-	RI84
96B-17	96B	229.63	-	2.73	-	(Calc.)	-	-	-	RI84
D35	D02	230.30	232.6	2.63	1.45	44.88	-	47.37	1.07×10^{-4}	MC90
D36	D02	232.60	234.2	2.61	1.45	44.27	-	52.01	5.81×10^{-3}	MC90
D37	D02	234.20	235.2	2.57	1.54	39.91	-	44.32	6.73×10^{-3}	MC90

Table 3.2.1-2c. Hydrogeologic properties core from the 240 -ft sedimentary interbed (continued).

Sample Number	Borehole Number	Depth Interval Top (ft)	Depth Interval Bottom (ft)	Particle Density (g/cc)	Bulk Density (g/cc)	Porosity %	Moisture Content (%, g/g)	Saturated Moisture Content (%, g/cc)	Vertical Hydraulic Conductivity (cm/s)	Reference[a]
D77B	D15	229.40	233.4	2.62	1.58	39.54	21.33	46.84	1.44 x 10 -7	MC90
D79A	D15	237.30	239.3	2.59	1.56	39.62	21.91	42.41	2.63 x 10 -7	MC90
D49XH	8801D	230.10	233.3	2.65	1.19	54.24	36.65	62.04	2.74 x 10 -3	MC90
D49XH-2	8801D	230.10	233.3	2.62	1.32	47.43	37.21	61.49	1.17 x 10 -5	MC90
D50	8801D	233.30	235.4	2.60	1.20	53.70	33.57	51.61	1.30 x 10 -4	MC90
D52	8801D	240.00	242.1	2.64	1.58	40.07	26.46	46.91	3.45 x 10 -6	MC90
0001	118	225.00	230.0	2.52	1.57	37.82	12.05	62.90	1.85 x 10 -4	MC90
0002	118	240.00	244.0	2.56	1.48	42.05	21.56	51.51	2.00 x 10 -5	MC90

Source:
BA76: Barraclough et al. (1976)
RI84: Rightmire (1984)
MC90: McElroy and Hubbell (1990)

Table 3.2.1-2d. Hydrogeologic properties of core from sedimentary interbeds below the 240-ft interbed.

Sample Number	Borehole Number	Depth Interval Top (ft)	Depth Interval Bottom (ft)	Particle Density (g/cc)	Bulk Density (g/cc)	Porosity %	Moisture Content (%, g/g)	Saturated Moisture Content (%, g/cc)	Vertical Hydraulic Conductivity (cm/s)	Reference[a]
	BG-87	559.00	561.0	2.65	-	-	-	-	-	BA76
	BG-88	519.00	521.0	2.60	1.98	40.20	42.90	-	-	BA76
0004	118	569.00	572.0	2.89	1.94	32.96	17.27	-	5.86 x 10 -6	MC90

Source:
BA76: Barraclough et al. (1976)
RI84: Rightmire (1984)
MC90: McElroy and Hubbell (1990)

Table 3.2.1-3. Mean values for water content, particle size, and hydraulic conductivity for the 30-ft, 110-ft, and 240-ft interbeds.

	Water Content (g/g, %)				Hydraulic Conductivity (cm/s)				Particle Size (mm)			
Interbed	Range	Mean[a]	N[b]	STD	Range	Mean[a]	N[b]	STD	Range	Mean[c]	N[b]	STD
30-ft	20.16 - 39.60	28.65	4	6.99	9.00×10^{-6} - 5.03×10^{-3}	1.37×10^{-3}	4	2.18×10^{-3}	0.0098 - 0.22	0.096	8	0.063
110-ft	15.10 - 37.20	22.13	8	6.76	3.59×10^{-9} - 3.47×10^{-3}	7.45×10^{-4}	6	1.25×10^{-3}	0.00053 - 4.20	0.632	23	1.212
204-ft	9.10 - 45.70	27.69	29	9.72	1.85×10^{-10} - 6.73×10^{-3}	6.44×10^{-4}	34	1.53×10^{-3}	0.0046 - 2.90	0.135	43	0.436

a. N = Number of samples
b. STD = Standard deviation
c. Mean of the medians (d50) for each interbed

Particle-size medians (d50) range from silt to sand (0.0098 to 0.22 mm) within the 30-ft interbed, from clay to gravel (0.00053 to 4.20 mm) within the 110-ft interbed, and from silt to gravel (0.0046 to 2.9) within the 240-ft interbed (Table 3.2.1-3). These wide ranges in particle-size medians reflect the heterogeneity of the interbed lithology. The widest range for particle-size medians is from the 110-ft interbed. Borehole geologic logs from the 110-ft interbed also indicate a greater variability in lithology for the 110-ft interbed than for the 30-ft and 240-ft interbeds.

Arithmetic averages of the interbed medians yielded the largest mean size of 0.632 mm for the 110-ft interbed and the smaller mean sizes, 0.096 mm and 0.135 mm for the 30-ft and 240-ft interbeds, respectively. The larger mean particle-size of the 110-ft interbed correlates with the borehole geologic logs, which also show generally coarser sediments within the 110-ft interbed.

The mean water contents for the 30- and 240-ft interbeds were similar, with a 28.65% mean water content for the 30-ft interbed and a 27.69% mean water content for the 240-ft interbed (Table 3.2.1-3). The 110-ft interbed was drier, with a 22.13% mean water content. The lower mean water content in the 110-ft interbed is consistent with the larger mean particle size for the 110-ft interbed. The coarse-textured sediments are generally less porous and will be drier than the finer-grained sediments under similar unsaturated tensions.

Hydraulic conductivities within each interbed ranged over several orders of magnitude (Table 3.2.1-3) and reflect the lithologic heterogeneity found within each interbed.

The mean hydraulic conductivities for the three major interbeds are all within two orders of magnitude. The 30-ft interbed exhibited the highest mean hydraulic conductivity of 1.37 E-03 cm/s. The 110-ft and 240-ft interbeds yielded similar mean hydraulic conductivities of 7.45 E-04 cm/s and 5.98 E-04 cm/s, respectively.

The hydraulic conductivities from the 110-ft interbed may be representative of only a portion of the sediments within the interbed. Only 6 samples from the 110-ft interbed were analyzed for hydraulic conductivity versus 32 from the 240-ft interbed (Table 3.2.1-3). As discussed in the studies from which the data were compiled, undisturbed core were more difficult to retrieve from the dry, coarse, unconsolidated sediments that are prevalent in the 110-ft interbed. The lack of core recovery from the coarser sediments within the 110-ft interbed may have biased the results towards lower hydraulic conductivities found in the finer-grained sediments of the 110-ft interbed.

In summary, the basalt flows beneath the SDA are interbedded with and overlain by sediments composed primarily of fine sand, silt, and clay. Three major interflow beds gave been identified at the SDA: the A-B (30-ft), the B-C (110-ft), and the C-D (240-ft) interbeds. Additional sedimentary interflow beds do exist, lower in the stratigraphic section, but are not well documented.

The 30-ft interbed forms a discontinuous basin fill within a topographic low on the underlying basalt flow. The sediments within the 30-ft interbed consist primarily of unconsolidated to partially consolidated sandy silts and silty fine sands. The dominant grain size appears to be silt, with only minor amounts of clays, sands, and gravels.

The 110-ft interbed is thicker and more laterally continuous than the 30-ft interbed. The upper surface of the interbed dips to the east, which may influence the movement of water from the spreading areas southwest of the RWMC to perched water bodies beneath the

SDA. The sediments consist of unconsolidated sandy silts to pebble gravels. Sands and gravels dominate the 110-ft interbed, with lesser amounts of silts and very little clays.

Of the three major interbeds, the 240-ft interbed is the most laterally continuous. The 240-ft interbed slopes to the east, almost parallel with the 110-ft interbed. This eastward dip may influence the movement of water from the spreading areas into perched water bodies beneath the SDA. The 240-ft interbed is dominated by sands and silts, with only minor amounts of clays and gravels. The sediments consist primarily of unconsolidated silt to coarse sands.

The 110-ft interbed exhibited a lower mean water content and higher mean particle-size than the 240- or 30-ft interbeds. The lower mean water content is consistent with the coarser materials found within the 110-ft interbed. Saturated hydraulic conductivity means for the 30-, 110-, and 240-ft interbeds were within two orders of magnitude. However, this may be misleading in the case of the 110-ft interbed, which is probably more permeable than the 30- or 240-ft interbeds. Core recovery of the coarser sediments in the 110-ft interbed has not been adequate to define hydraulic conductivities representative of this interbed.

The dominant clay type in the 30-ft interbed is illite, and the CEC values ranged from 0.9 to 18 meq/100 g of soil. The lateral discontinuity and low CEC of the 30-ft interbed provide only an intermittent barrier to contaminant migration. The 110- and 240-ft interbeds are more laterally continuous and thicker than the 30-ft interbed, which provides more of a matrix for contaminant adsorption. However, the 110-ft interbed had a low clay percentage and low CEC values. The 240-ft interbed was the most variable with respect to bulk and clay mineralogy.

3.2.2 Magnuson and McElroy, 1993

In Magnuson and McElroy, 1993, estimations of net infiltration into the vadose zone at the RWMC were made based on data collected during the Subsurface Investigation Program (DOE, 1983). The data that was used consisted of in situ moisture contents measured on fifteen (15) samples retrieved during drilling from the 30', 110', and 240' interbeds. These samples were also hydrologically characterized for their moisture characteristic curves and saturated hydraulic conductivity. The in situ moisture contents and moisture characteristic curves for each sample are contained in McElroy and Hubbell (1990).

Table 3.2.2-1 shows the representative characteristic curves for the interbeds. The 110' and 240' interbed representative moisture characteristic curves are used in the RWMC low-level waste radiological performance assessment (Maheras et al., 1994, Table 3-2).

Table 3.2.2-1. Representative characteristic curves for the 30', 110' , and 240' interbed samples (from Magnuson and McElroy 1993).

		θs	θr	α	n
	cm/s	cm/cm	cm/cm	1/cm	
30' interbed	2.63×10^{-4}	0.5970	0.0411	0.010325	1.4510
110' interbed	6.25×10^{-3}	0.482	0.043	0.032	2.5338
240' interbed	1.53×10^{-4}	0.5708	0.1444	0.017751	1.3753

3.2.3 Barraclough et al., 1976

Barraclough et al., 1976 describes the results of a study made in 1970-1974 to evaluate the geohydrologic and geochemical controls on subsurface migration of radionuclides from pits and trenches in the Idaho National Engineering Laboratory (INEL) solid waste burial ground and to determine the existence and extent of radionuclide migration, if any, from the burial ground. A total of about 1,700 sediment, rock, and water samples were collected from 10 observation wells drilled in and near the burial ground of Idaho National Engineering Laboratory, formerly the National Reactor Testing Station (NRTS).

Within the burial ground area, the subsurface rocks are composed principally of basalt. Wind- and water-deposited sediments occur at the surface and in beds between the thicker basalt zones. Two principal sediment beds occur at about 110 feet (34 metres) and 240 feet (73 metres) below the land surface. The average thickness of the surficial layers is about 15 feet (4.6 metres) while that of the two principal subsurface layers is 13 and 14 feet (4.0 and 4.3 metres), respectively. The water table in the aquifer beneath the burial ground is at a depth of about 580 feet (177 metres).

Table 3.2.3-1 is a tabulation of various physical characteristics of sedimentary samples from the INEL Burial Ground wells.

Table 3.2.3-1. Various physical characteristics of sedimentary samples from the INEL Burial Ground wells (Barraclough, et al. 1976, Table A-IV).

Local well number	Depth interval				Specific gravity	Bulk density (g/cm^3)	Porosity (%)	Moisture content (%)	Vertical hydraulic conductivity			
	Top		Bottom						Pore pressure (psig)		Confining pressure (psig)	m/day
	ft	in.	ft	in.					Input	Output		
BG-87	230		231	6	–	–	–	–	–	–	–	–
BG-87	236		237	6	2.73	2.33	35.7	37.7	2.8	0	11	2.5×10^{-2}
BG-87	242		243	6	2.56	1.87	42.7	40.2	104	90	362	3.2×10^{-4}
BG-87	559		561		2.65	–	–	–	–	–	–	–
BG-88	108	6	111		3.03	2.41	28.1	23.2	–	–	–	–
BG-88	112	6	113	6	3.02	2.34	30.1	23.0	–	–	–	–
BG-88	237		238	6	2.78	1.95	46.3	45.7	4.0	0	235	1.3×10^{-1}
BG-88	247	6	249		2.64	1.91	42.1	38.4	36	0	275	3.5×10^{-5}
BG-88	253	6	255		–	–	–	–	150	116	400	7.9×10^{-7}
BG-88	265	6	267		2.64	2.15	35.0	42.7	31	0	296	3.1×10^{-6}
BG-88	519		521		2.60	1.98	40.2	42.9	–	–	–	–
BG-89	110		115		–	–	–	–	–	–	–	–
BG-89	241		241	7	2.70	2.07	35.6	33.0	86	0	298	1.6×10^{-7}
BG-89	243	6	245	6	2.66	1.95	38.1	29.6	14	0	271	6.1×10^{-5}
BG-89	250	10	252	2	2.71	2.20	28.5	26.1	34	0	250	5.8×10^{-5}
BG-89	295		296	4	–	–	–	–	–	–	–	–
BG-89	365		371		–	–	–	–	–	–	–	–
BG-89	545		550		–	–	–	–	–	–	–	–
BG-89	565		575		–	–	–	–	–	–	–	–
BG-89	600		605		–	–	–	–	–	–	–	–
BG-89	640		645		–	–	–	–	–	–	–	–
BG-90	108		113		–	–	–	–	–	–	–	–

Table 3.2.3-1. (continued 2/3)

Local well number	Depth interval				Specific gravity	Bulk density (g/cm^3)	Porosity (%)	Moisture content (%)	Vertical hydraulic conductivity			
	Top		Bottom						Pore pressure (psig)		Confining pressure (psig)	m/day
	ft	in.	ft	in.					Input	Output		
BG-90	249		250		2.76	1.80	46.1	30.6	1.9	0	18	2.9×10^{-2}
BG-90	250		251	6	2.64	1.70	53.3	–	–	–	–	–
BG-90	250		251	6	–	–	–	–	–	–	–	–
BG-90	386		387		–	–	–	–	–	–	–	–
BG-90	610		612		–	–	–	–	–	–	–	–
BG-91	26		32		2.64	1.90	38.8	27.5	40	0	1/	1.3×10^{-2}
BG-91	74		92		2.66	1.90	35.5	19.3	1.2	0	1/	3.0
BG-91	105		107		2.67	–	–	–	–	–	–	–
BG-91	233	9	236	3	2.68	1.34	53.4	9.1	1.1	0	1/	7.2×10^{-1}
BG-91	236	3	238	9	2.74	1.56	50.4	–	5.0	0	1/	2.6×10^{-1}
BG-91	243	2	245	1	2.64	2.06	30.3	21.8	–	–	–	–
BG-92	2?6		5		2.65	1.87	34.3	12.9	60	0	1/	5.5×10^{-4}
BG-92	225	6	228		2.66	1.58	45.1	11.7	11.7	0	1/	2.6
BG-92	233	6	236		2.71	1.87	37.6	18.1	10	0	1/	2.7×10^{-2}
BG-92	244	7	246	2	2.65	2.06	35.1	34.1	10	0	1/	2.1×10^{-6}
BG-93	12	1	14		2.64	1.81	41.6	27.3	50	0	1/	2.6×10^{-4}
BG-93	88	3	90	4	–	–	–	–	–	–	–	–
BG-93	103		105		2.86	–	–	–	–	–	–	–
BG-93	105		110		2.87	–	–	–	–	–	–	–
BG-93	228	9	229	10	2.75	1.73	42.2	14.4	1.3	0	1/	5.5×10^{-2}
BG-94	6	6	8	3	2.67	2.02	30.5	16.4	60	0	1/	2.7×10^{-4}
BG-94	8	3	8	8	2.67	–	21.0	–	140	0	350	9.6×10^{-6}
BG-94	110		112	6	2.67	1.85	36.5	15.1	1.2	0	1/	7.6×10^{-1}

Table 3.2.3-1. (continued 3/3)

Local well number	Depth interval Top ft	Top in.	Bottom ft	Bottom in.	Specific gravity	Bulk density (g/cm^3)	Porosity (%)	Moisture content (%)	Vertical hydraulic conductivity: Pore pressure (psig) Input	Pore pressure (psig) Output	Confining pressure (psig)	m/day
BG-94	228	9	231	3	2.68	1.86	40.8	27.3	1.2	0	1/	1.6×10^{-2}
BG-94	236	3	238	9	2.72	1.73	41.1	13.4	1.2	0	1/	2.3×10^{-1}
BG-94	244	9	247	10	2.67	2.11	33.9	35.4	59	0	1/	7.2×10^{-5}
BG-94	270	3	272	4	2.60	–	–	–	84	0	1/	5.6×10^{-5}
BG-95	10		12	6	2.66	1.70	41.0	13.2	20	0	1/	7.9×10^{-3}
BG-95	17	6	20		2.65	1.53	43.4	3.15	1.2	0	1/	5.4×10^{-1}
BG-95	106		107		2.66	1.62	44.7	15.4	1.2	0	1/	1.5×10^{-1}
BG-95	109	6	112		2.67	2.30	20.6	17.8	59	0	1/	3.1×10^{-6}
BG-95	229	3	231	9	2.68	1.70	46.3	26.4	1.2	0	1/	2.8×10^{-1}
BG-95	231	9	233	3	2.68	1.83	42.5	29.0	1.2	0	1/	9.3×10^{-1}
BG-96	12	10	15		2.66	1.94	37.6	27.7	1.2	0	1/	6.0×10^{-1}
BG-96	101	11	103		–	–	–	–	–	–	–	–
BG-96	116	7	119	1	2.64	1.87	43.2	37.2	60	0	1/	6.6×10^{-6}
BG-96	224	1	226	7	2.67	1.96	37.1	27.6	56	0	310	1.9×10^{-3}

1/ Samples run in original liners with no lateral loading applied. Uncalibrated axial load sufficient to ensure seating in apparatus was applied.

3.3 McElroy and Hubbell, 1990

Selected sediment samples from surficial and interbed sediments beneath the Radioactive Waste Management Complex (RWMC) were analyzed for physical and hydrological properties to provide information pertinent for characterizing hydrogeologic conditions at the RWMC. The limitations and representativeness of the data should be considered when using measurement results for water flow or contaminant transport calculations. Knowledge of sample locations, sampling methodology, sample history, sample handling, and analytical methods provides necessary background information for use of the results. This report summarizes background sample information, analytical results, and limitations of the data.

The procedures used to collect, handle, and ship samples will be discussed, along with methods used to measure and analyze samples. Results for each of the tested parameters are presented as well as a discussion on limitations of the data.

Table 3.3-1 is the data for archived core samples from RWMC.

Table 3.3-1. Data for archived core samples from RWMC (analyzed August -- October 1989) (from Table 1 of McElroy and Hubbell, 1990).

					Sample Numbers	
Core Id.	Well No.	Date Sampled	Depth (Ft)	Texture	Hydrau. Prop. Analyses	Air Perm. Analyses
D35	D02	10-31-86	230.3 - 232.6	Sand w/clay	D86D02XD35XH	D86D02XD35XA
D36	D02	11-03-86	232.6 - 234.2	Sand	D86D02XD36XH	D86D02XD36XA
D37	D02	11-03-86	234.2 - 235.2	Sand	D86D02XD37XH	D86D02XD37XA
D67	D15	09-09-87	108.6 - 111.0	Clay	D87D15XD67XH	
D77	D15	09-10-87	229.4 - 233.4	Silty clay	D87D15XD77BH	D87D15XD77AA
D79	D15	09-18-87	237.3 - 239.3	Clay	D87D15XD79AH	D87D15XD79AA
D89	D10	09-18-87	31.5 - 34.7	Silty sand	D87D10XD89XH	
D90	D10	09-18-87	34.7 - 36.0	Silty sand	D87D10XD90XH D87D10XD90XH-2	
D49	8801D	07-25-88	230.1 - 233.3	Silty clay	D888801D49XH D888801D49XH-2	D888801D49A
D50	8801D	07-25-88	233.3 - 235.4	Silty clay	D888801D50XH	D888801D50XA
D52	8801D	07-25-88	240.0 - 242.1	Silty clay	D888801D52XH	D888801D52XA
ST06	W24	08-01-86	7.4 - 8.3	Clay	D86W24XST06H	D86W24XST06A
ST09	W06	08-06-86	1.7 - 2.7	Silt	D86W06XST09H	
ST10	W06	08-06-86	11.0- 11.8	Silt	D86W06XST10H	D86W06XST10A
ST20	W09	09-11-86	6.0 - 7.0	Clayey sand	D86W09XST20H	D86W09XST20A
USGS-1	118	9-87	225.0 - 230.0	Silt	D89118X0001H	D89118X0001A
USGS-2	118	9-87	240.0 - 244.0	Silty clay	D89118X0002H	D89118X0002A
USGS-3	118	9-87	244.0 - 247.0	Clayey silt	D89118X0003H	
USGS-4	118	9-87	569.0 - 572.0	Clay	D89118X0004H	D89118X0004A

3.3.1 Moisture Content

Moisture content reflects the mass of water within the sample at the time of analysis at the laboratory.

Table 3.3-2 presents a comparison of Daniel B. Stephens and Associates, Inc. (DBS) and Petroleum Testing Services, Inc. (PTS) moisture content data (gravimetric) for the samples. Table 3.3-2 also includes Field and Idaho Research Center (IRC) Laboratory data sets, which are moisture content measurements determined by Geosciences Laboratory personnel. These moisture contents were determined shortly after collection of the samples and are included for completeness. The techniques used for moisture determination for samples identified as Field, IRC and DBS are presented in Appendix F and the methods used by PTS Laboratory are included in Appendix G of McElroy and Hubbell, 1990.

Representativeness of in-situ moisture contents depends on how well the samples were sealed prior to analysis, the amount of time between sampling and analysis, and sample handling during the analysis. For practical purposes, all samples were adequately sealed in the field to ensure representative moisture contents. IRC, DBS, and PTS samples were sealed in the original sampling container with plastic caps, electrical tape, and three plastic bags. Field samples were placed in aluminum cans and sealed with electrical tape. The sample handling and the elapsed time between sample collection and moisture determination varies between methods as does the sample handling during analysis.

Field samples were analyzed for moisture content within 24 hours after sample collection. These values are the most representative of in-situ moisture content.

IRC Laboratory samples were analyzed for moisture content while preparing the samples for analyses of radionuclides (generally several months following collection). Samples were exposed to the atmosphere for several minutes prior to analyses so the moisture contents are presumed to be lower than in situ conditions. These data are presented because they provide a lower limit on moisture contents for several samples (D35, D36, ST09, and D37) that otherwise would not be available.

DBS and PTS samples were analyzed one to three years following sample collection. The long storage time has probably allowed some moisture to escape from the storage container or redistribute within the container, changing the moisture content results. Samples D35, D36, D37 and ST09 were saturated for hydraulic conductivity measurements (performed in-house), prior to being sent to contract laboratories for the physical properties analyses. Therefore, moisture contents measured by DBS and PTS for these samples are not representative of field moisture contents.

Table 3.3-2 presents data considered representative of in-situ soil moisture conditions. The most representative moisture contents are the Field values, which were determined immediately following sampling. Moisture contents for DBS and PTS samples are within 10% of the Field values, suggesting long-term storage of samples did not significantly alter moisture contents.

Data presented in Table 3.3-2 indicates variation in moisture contents between collocated samples. Collocated samples are samples taken from the same core tube, adjacent to each other. The analyses of both collocated samples were completed at the DBS laboratory, using identical procedures. Collocated samples D49 and D49-2 show little variation, whereas D90 and D90-2 have a 32% variation between samples. The differences in moisture content may be due to textural differences rather than measurement errors.

Table 3.3-2. Gravimetric moisture contents (in %) from RWMC sediment samples (mass) (from Table 6 of McElroy and Hubbell, 1990).

Core I.D.	Field	Gravimetric moisture contents (in %) IRC	DBS	PTS	Variation %	Saturation[a] %
D35	--	14.0	--	--	--	--
D36	--	12.7	--	--	--	--
D37	--	14.3	--	--	--	--
D49	--	20.6	36.6	29.5	24	78.7
D49-2	--	--	37.2	--	02[b]	71.0
D50	--	22.2	33.6	25.0	34	75.2
D52	--	--	26.5	25.0	06	>100
D67	--	17.2	26.8	--	--	>100
D77	--	16.5	21.3	25.9	28	85.4
D79	--	22.8	21.9	21.1	04	86.5
D89	--	15.5	20.2	--	--	45.8
D90	--	--	27.3	--	--	58.7
D90-2	--	--	39.6	--	32[b]	>100
ST06	22.6	--	20.51	19.4	05	57.2
ST10	27.4[c]	--	28.7	29.6	04	89.6
ST20	--	--	25.1	17.9	40	70.3
USGS1	--	--	12.0	7.7	44	50.0
USGS2	--	--	21.6	21.3	01	76.1
USGS4	--	--	17.3	25.8	33	>100
Mean value			26.0	22.5	15	72.1

Gravimetric moisture contents in percent.
a. Percent saturation for DBS laboratory samples.
b. Variations between duplicate samples.
c. Taken form sample immediately (11 in.) above sample.

Different analytical techniques were performed by DBS and PTS. Table 3.3-2 presents variation (%) between results from the two laboratories. The variation is calculated by

$$\frac{\text{DBS - PTS}}{\text{PTS}} \text{ X } 100.$$

The two techniques should produce equivalent results. Samples D52 and D79 show consistency between the DBS and PTS laboratories. Other samples show poor correlations with variations between laboratory results exceeding 12% moisture content. Previous analyses of moisture content data collected from other RWMC drilling samples (Hubbell et al. 1986, 1987), indicates moisture contents can vary significantly between samples depending on textural differences (sand, silt, and clay). Variations in the archived samples are probably due to textural differences within the samples rather than analytical variations.

Moisture contents for sediments ranging in texture from clay to silty sands were 17 to 36%. One sample of sand was analyzed and it had a moisture content between 7 and 12%. This low value corresponds with the field measurements for sand determined in previous investigations from other boreholes (Hubbell et al., 1986 and 1987).

Table 3.3-2 presents percent saturation of samples analyzed by DBS laboratory. This value is determined by dividing the initial moisture content by calculated porosity. These values have been rounded to the nearest percent. They represent the percentage of moisture content divided by the total volume of voids. Percent saturation in the samples range from 50 to 100%. The average saturation for these 16 samples is 72%.

In summary, moisture content data presented in Table 3.3-2 is of limited usefulness due to the extended time of storage prior to analyses. However, these values can be used to provide a low estimate of in-situ moisture contents. The most accurate moisture content values are the Field data.

3.3.2 Dry Bulk Density

Dry bulk density is the ratio of the mass of dried soil to its total volume. It is reported in units of grams per cubic centimeter (g/cm^3). Dry bulk density can be influenced by disturbance of the soil either by compaction or by breaking the sample apart during sampling and handling. Laboratory results are in Appendix A-2 and analytical methods are in Appendix F of McElroy and Hubbell, 1990.

A summary of dry bulk densities is in Table 3.3-3. It presents a comparison of dry bulk densities calculated by PTS and DBS laboratories. The column titled Variation is the percent variation between the laboratory results. Bulk densities reported by the two analytical labs compare favorably. Three samples vary more than 10% between the laboratory analyses.

Collocated samples are taken adjacent to one another and variations in dry bulk density measurements are anticipated. A comparison of collocated samples D49, D49-2 and D90, D90-2 indicate variations of 10 and 9%, which is within the range of higher variations measured between the samples.

Bulk densities for all the samples vary between 1.18 and 1.94 g/cm^3. Bulk densities cited in the literature for these media are generally within the range of 1.2 to 1.6 g/cm^3. The mean value of 1.39 g/cm^3 is well within the range of expected values of dry bulk density. The bulk density of one sample, USGS-4 is higher than anticipated and should not be used as a representative value (this sample was described as highly compacted). The remaining values fall in the accepted range.

Table 3.3-3. Dry bulk density of RWMC sediment samples (from Table 7 of McElroy and Hubbell, 1990).

Sample I.D.	Dry Bulk Density		Variation (%)
	DBS	PTS	$\frac{\text{DBS-PTS}}{\text{PTS}}$ X 100
D35	1.45	1.51	04
D36	1.45	1.50	04
D37	1.33	1.76	24
D49	1.19	1.30	09
D49-2	1.32	--	10[a]
D50	1.20	1.60	25
D52	1.58	1.50	05
D67	1.61	--	--
D77	1.58	1.59	01
D79	1.56	1.66	06
D89	1.23	--	--
D90	1.18	--	--
D90-2	1.29	--	09[a]
ST06	1.35	1.41	04
ST09	1.33	--	--
ST10	1.42	1.26	13
ST20	1.35	1.41	04
USGS-1	1.57	1.46	07
USGS-2	1.48	1.43	04
USGS-4	1.94	1.76	10
Mean Value	1.39	1.27	09

a. Variation between collocated samples.
All values are reported in grams per cubic centimeter except the variation of laboratory values.

3.3.3 Porosity

Porosity is an index of the pore volume of the soil compared to the total volume of a sample. Porosity measurements are affected by sample disturbance or compaction prior to analysis. Porosity was determined by two laboratories, using different laboratory methods. Methods and procedures used for analyses are described in McElroy and Hubbell, 1990 Appendix F for DBS samples and Appendix G for samples sent to PTS. DBS calculated porosity using measured dry bulk density and specific gravity of the samples. The value obtained represents total porosity, generally higher than effective porosity. PTS measured effective porosity, using a helium porosimeter. Effective porosity, as determined by PTS, may be less than total porosity.

Comparison of data from the two laboratories is presented in Table 3.3-4. Laboratory data are presented in Appendix A-2 of McElroy and Hubbell, 1990. Table 3.3-4 includes a calculated variation of porosity between the two laboratories (DBS and PTS) and between collocated samples. This variation is presented as a percent difference. Most samples have a 12 to 16% variation between laboratory results. Three of 13 samples (D50, D37, and USGS1) exceeded this variation. Variation of readings between samples may reflect actual differences in the porosity of samples taken from the same core.

Measurements from core samples indicate porosity ranges between 32 and 55%. The range of normal values of porosity for sediments is 25-50% for sand, 35 to 50% for silt, and 40 to 70% for clay (Freeze and Cherry, 1979). Measured values fall within the range of anticipated values for the various sediment types. Mean porosity measurements (calculated) indicate total porosity is slightly higher than measured (effective) porosity by 4%.

Table 3.3-4. Comparison of porosity measurements for sediment samples from the RWMC (from Table 8 of McElroy and Hubbell, 1990).

Sample I.D.	Porosity (%)		Variation(%)
	DBS	PTS	$\frac{DBS-PTS}{PTS} \times 100$
D35	44.88	43.1	04
D36	44.27	43.5	02
D37	39.91	34.2	17
D49	55.24	51.4	07
D49-2	47.43	--	16[a]
D50	53.70	40.7	32
D52	40.07	43.3	07
D67	37.99	--	--
D77	39.54	40.1	02
D79	39.62	37.2	04
D89	54.43	--	--
D90	55.06	--	--
D90-2	48.99	--	12[a]
ST06	48.43	46.4	04
ST09	48.06	--	--
ST10	45.62	52.8	14
ST20	48.31	46.8	03
USGS-1	37.82	45.5	17
USGS-2	42.05	46.0	09
USGS-4	32.96	35.7	08
Mean values	45.21	43.3	04

a. Ratio between collocated samples.

3.3.4 Particle-Size Distribution

Particle-size analysis is the measurement of sizes of individual particles in a soil sample. Soil aggregates are disaggregated by mechanical, chemical, or ultra-sonic means, and particles are separated according to size by sieving or sedimentation (hydrometer) methods. Appendix F of McElroy and Hubbell, 1990 describes sieving and hydrometer methods used to determine particle-size distributions of sediments from the RWMC cores.

Particle-size distribution of sediments or soils, in large part, determines the interactions of the soil with fluids and solutes. The proportion of clay-sized particles may affect hydrologic properties and chemical interactions of sediment. Clay-sized particles contribute most of the inorganic surface area to soils, affecting the physical adsorption of molecules, swelling and shrinking of soils, water retention and movement, and cation-exchange capacity.

Particle-size distributions are presented in Tables 3.3-5 and 3.3-6. Table 3.3-5 presents a summary of the results. The columns in Table 3.3-5 for d_{10}, d_{50}, and d_{60} indicate the largest diameter of the particles representing 10, 50, and 60% of the particles. The diameter d_{50} is the median diameter of the particles in the sediment, dividing the size distribution into two equal parts. The uniformity coefficient, Cu, where Cu = d_{60}/d_{10} provides a method for comparing the grading pattern of the sediment, i.e. poorly graded or well graded. The smaller the Cu, the more uniform and continuous the grain-size distribution curve is expected to be.

Table 3.3-6 presents the distributions as the percent retained in each size interval. Percent retained for sands and gravels were determined by mechanical sieving, and the size intervals are based on sieve sizes used by the laboratory. Distribution of fines (silts and clays) was determined by hydrometer analyses. Calculation of percent retained for fines was based on a linear interpolation of laboratory results because standard size intervals were not reported. Raw data, laboratory calculations, and grain-size plots are presented in Appendix A-3 of McElroy and Hubbell, 1990.

Results of collocated samples (D49-2 and D49, D90-2 and D90) were compared. Differences in values between collocated samples for the d_{10}-, d_{16}-, d_{30}-, d_{50}-, and d_{84}-size fractions ranged from 1 to 17%, indicating that there were textural differences between adjacent samples.

Several samples did not undergo the complete particle-size analysis. Sample USGS-4 was not mechanically sieved and samples D67, D36, and D37 were not analyzed using the hydrometer because of insufficient sample size. Results of particle-size analyses should be representative of in-situ conditions since sample holding and storage will not affect particle-size distributions.

Table 3.3-5. Summary of particle-size analysis for sediment samples from the RWMC (from Table 9 of McElroy and Hubbell, 1990).

	Particle-size Analysis			Uniformity Coefficient
Sample Number	d_{10} (mm)	d_{50} (mm)	d_{60} (mm)	C_u
D35	0.0080	0.100	0.130	16.3
D36	0.1100	0.220	0.280	2.5
D37	0.0910	0.230	0.290	3.2
ST09	0.0013	0.075	0.080	61.5
ST10	0.0130	0.120	0.130	10.0
ST20	0.0500	0.120	0.140	2.8
ST06	--a	0.079	0.090	--b
D89	0.011	0.055	0.070	6.4
D90	0.0075	0.075	0.085	11.3
D90-2	0.0090	0.076	0.082	9.1
D67	--a	0.160	0.170	--b
D77	--a	0.020	0.071	--b
D79	0.0022	0.013	0.019	8.6
D49	0.0018	0.012	0.015	8.3
D49-2	0.0023	0.013	0.018	7.8
D50	0.0014	0.020	0.071	50.7
D52	0.0055	0.098	0.120	21.8
USGS-1	0.0070	0.090	0.100	14.3
USGS-2	0.0011	0.080	0.095	86.4
USGS-4	--a	0.018	0.029	--b

a. Diameter was not reached with the test(s) specified
b. Values are dependent on diameters that were not reached

Table 3.3-6. Particle-size distribution for sediment samples from the RWMC (from Table 10 of McElroy and Hubbell, 1990).

			Percent Retained (mm)								
	Depth Interval (ft)		Clay	Silt	Sand					Gravel	
Sample Number	Top	Bottom	<0.005	0.005-0.075	0.075-0.106	0.106-0.212	0.212-0.425	0.425-1.18	1.18-2.0	2.0-3.35	3.35-4.75	>4.75
Surficial Sediments												
ST09	1.2	2.7	18.11	35.91	31.09	14.57	0.3	0.02	0	0	0	0
ST20	6.0	7.0	9.92	24.84	12.43	29.39	23.39	0.02	0.01	0	0	0
ST06	7.4	8.3	25.4	20.56	22.46	30.91	0.42	0.25	0	0	0	0
ST10	11.0	11.8	6.42	25.76	22.24	42.78	1.64	0.07	0	0.04	0	1.05
30-ft Interbed												
D89	31.5	34.7	4.74	58.87	12.81	14.23	8.12	1.21	0.02	0	0	0
D90	34.7	36.0	7.02	42.91	29.54	19.2	1.23	0.07	0.01	0.02	0	0
D90-2	34.7	36.0	5.63	42.04	39.03	12.16	1.05	0.09	0	0	0	0
110-ft Interbed												
D67	108.6	111.0	------12.22------		18.35	44.08	24.25	1.1	0	0	0	0
240-ft Interbed												
D36	232.6	234.2	-------4.43------		4.71	36.42	36.53	16.82	0.95	0.09	0.05	0
D37	234.2	235.2	-------6.07------		6.37	32.46	35.21	18.01	1.62	0.11	0.15	0
D35	230.3	232.6	7.28	24.85	19.62	23.63	18.32	6.02	0.18	0.1	0	0
D77	229.4	233.4	22.25	39.7	12.95	23.28	1.72	0.09	0.01	0	0	0
D79	237.3	239.3	21.96	53.52	15.19	9.32	0	0	0.01	0	0	0
D49	230.1	233.3	22.0	57.44	9.07	7.63	3.54	0.32	0	0	0	0
D49-2	230.1	233.3	19.92	58.76	11.84	7.91	1.47	0.09	0.01	0	0	0
D50	233.3	235.4	21.65	41.55	18.66	14.05	3.89	0.2	0	0	0	0
USGS-1	225	230	7.47	29.7	25.05	29.31	8.07	0.39	0.01	0	0	0
USGS-2	240	244	25.47	20.51	20.44	24.33	8.61	0.64	0	0	0	0
D52	240	242	9.89	6.85	41.92	29.57	11.36	0.39	0.02	0	0	0
>240-ft Interbed												
USGS-4	569	572	28.87	43.33	---------------------------- 27.760 ----------------------------					0	0	0

3.3.5 Particle Density

Mean particle density (specific gravity) is the ratio of the mass of solids to the volume of solids. The pycnometer method was used to measure the mean particle density of the soil samples (Appendix F of McElroy and Hubbell, 1990.). Two pycnometer trials were performed for each sample and the average particle density of the two trials is presented in Table 3.3-7. Laboratory data are presented in Appendix A-4 of McElroy and Hubbell, 1990. The particle density results appear representative of the in-situ field conditions.

Particle densities for samples fell within or close to the range for quartz and aluminosilicate clays (2.6 to 2.7 g/cm^3), with the exception of USGS-4. Sample USGS-4 had a measured particle density of 2.89 g/cm^3, which was 0.17 g/cm^3 above the expected range. Both pycnometer trials for USGS-4 showed consistently high particle densities. Sample USGS-4 was the deepest sample, collected at approximately 570 ft below land surface, near the water table. According to the sample description, the sample texture was clay with basalt. The basalt was massive and was not included in the hydraulic parameters measurements. Formation of weathering products (such as iron oxides) may have increased the particle density of the sample. The measurement appears to be representative of the sediment at that depth. There is no reason to suspect the measurement was in error.

The precision between sample measurements was excellent. Two trials were performed on all but one sample (which did not have enough leftover sample). Excellent agreement was obtained, within 2% or less. Collocated samples (D49 and D90) showed similar agreement.

Table 3.3-7. Summary of particle-density analysis for sediment samples from the RWMC (from Table 11 in McElroy and Hubbell, 1990).

Sample Number	Particle Density (g/cc)
D35	2.63
D36	2.61
D37	2.57
ST09	2.57
ST10	2.62
ST20	2.62
ST06	2.62
D89	2.71
D90	2.63
D90-2	2.63
D67	2.59
D77	2.62
D79	2.59
D49	2.65
D49-2	2.62
D50	2.60
D52	2.64
USGS-1	2.52
USGS-2	2.56
USGS-4	2.89

3.3.6 Moisture-Retention Characteristics

The wetness of a soil is functionally dependent upon the matric potential (or negative pressure head) of the soil. Graphical representation of this relationship is called the soil-moisture characteristic curve, moisture-retention characteristic curve, or water-release curve.

Two methods were used to describe the moisture-retention characteristics of the RWMC sediments: 1) the hanging column method and 2) the pressure plate method. The hanging column method was performed in the pressure range of 0 to approximately 0.4 bars of tension and the pressure plate method was used above 0.4 bars of tension. The methods and procedures used are described in Appendix F of McElroy and Hubbell, 1990.

Saturated volumetric moisture contents (equivalent to effective porosity) were determined for samples prior to the start-up of moisture-release measurements. Table 3.3-8 lists saturated moisture contents by soil texture. The measurements for clays are lower than expected (i.e. 34.81% for USGS-4). The saturated moisture contents probably represent minimum values and should be used with caution. Moisture contents could have been reduced by compaction during coring as well as by microbial growth during extended storage of the samples. Sample USGS-4 was described as highly compacted by the laboratory technician. Collocated samples D49 and D49-2, and D90 and D90-2 showed only minor variations (1.2%) in saturated moisture contents.

Table 3.3-9 is a summary of moisture-retention characteristics. The laboratory data are presented in Appendix A-5 of McElroy and Hubbell, 1990. Moisture-release curves for samples USGS-4, D79, D67, ST06, USGS-2, D77, and D52 have unusually uniform, steep slopes, which do not show much change in the low suction range. These samples appear to be affected by compaction. Compaction decreases the volume of the larger pores, which reduces the saturated water content and initial moisture loss from the application of low suctions (Hillel, 1980). The remaining moisture-release curves are within the expected ranges and show patterns consistent with their general textures.

Moisture-release curves from collocated samples (D90 and D49) show differences in patterns and values. The moisture-release curves exhibit lower moisture contents for specific pressure heads for samples D49 and D90 than for their respective collocated samples D49-2 and D90-2. Heterogeneity between adjacent samples may have affected the measurements.

Table 3.3-8. Saturated moisture content (% by volume, cm^3/cm^3) listed by texture (from Table 12 in McElroy and Hubbell, 1990).

	Clay	Silty Clay	Silt	Clayey Sand	Silty Sand	Sand
D35	--	--	--	47.37	--	--
D36	--	--	--	--	--	52.01
D37	--	--	--	--	--	44.32
ST09	--	--	51.08	--	--	--
ST10	--	--	49.62	--	--	--
ST20	--	--	--	47.92	--	--
ST06	45.06	--	--	--	--	--
D89	--	--	--	--	55.40	--
D90	--	--	--	--	62.22	--
D90-2	--	--	--	--	61.51	--
D67	47.24	--	--	--	--	--
D77	--	46.84	--	--	--	--
D79	42.41	--	--	--	--	--
D49	--	62.04	--	--	--	--
D49-2	--	61.49	--	--	--	--
D50	--	51.61	--	--	--	--
D52	--	46.91	--	--	--	--
USGS-1	--	--	62.90	--	--	--
USGS-2	--	51.51	--	--	--	--
USGS-4	34.81	--	--	--	--	--

Table 3.3-9. Summary of moisture-retention characteristics (from Appendix A Table 5 of McElroy and Hubbell, 1980).

Sample Number	Pressure Head (-cm of water)	Moisture Content (% cm^3/cm^3)
D86W06XST10H	0.0	49.62[a]
	41.6	46.05
	102.5	43.11
	208.5	38.95
	509.9	31.71
	1019.8	24.93
	5088.8	19.16
	15297.0	14.21
D86W09XST20H	0.0	47.92[a]
	38.4	41.74
	101.0	36.50
	210.0	33.43
	509.9	27.53
	1019.8	21.14
	5088.8	18.45
	15297.0	10.12
D86W24XST06H	0.0	45.06[a]
	81.5	41.77
	156.0	38.48
	213.0	37.08
	509.9	31.46
	1019.8	28.96
	5088.8	27.51
	15297.0	22.42
D87D10XD89XH	0.0	55.40[a]
	42.2	48.53
	102.0	39.72
	204.0	25.40
	509.9	15.30
	1019.8	10.82
	5088.8	7.48
	15297.0	3.85
D87D10XD90XH	0.0	62.22[a]
	47.5	57.47
	110.0	51.15
	212.0	38.58
	509.9	29.81
	1019.8	24.55
	5088.8	22.36
	15297.0	15.80

Table 3.3-9. (continued)

Sample Number	Pressure Head (-cm of water)	Moisture Content (% cm^3/cm^3)
D87D10XD90XH-2	0.0	61.51[a]
	84.0	57.87
	158.0	54.07
	221.0	51.19
	509.9	44.19
	1019.8	37.60
	5088.8	29.16
	15297.0	22.17
D87D15XD67XH	0.0	47.24[a]
	82.6	48.30
	158.0	48.08
	219.0	47.92
	509.9	46.88
	1019.8	45.65
	5088.8	43.50
	15297.0	37.56
D87D15XD77BH	0.0	46.84[a]
	83.4	45.56
	158.0	44.68
	215.0	44.14
	509.9	41.60
	1019.8	39.39
	5088.8	37.41
	15297.0	27.02
D87D15XD79AH	0.0	42.41[a]
	81.6	41.96
	156.5	41.34
	215.5	40.81
	509.9	37.76
	1019.8	35.55
	5088.8	32.97
	15297.0	23.36
D888801D49XH	0.0	62.04[a]
	34.5	48.28
	103.0	45.23
	206.0	43.15
	509.9	39.81
	1019.8	35.15
	5088.8	24.11
	15297.0	19.49

Table 3.3-9. (continued)

Sample Number	Pressure Head (-cm of water)	Moisture Content (%cm^3/cm^3)
D888801D49XH-2	0.0	61.49[a]
	81.2	58.20
	153.0	57.00
	211.0	56.34
	509.9	51.28
	1019.8	45.85
	5088.8	36.61
	15297.0	25.83
D888801D50XH	0.0	51.61[a]
	78.9	41.37
	152.0	40.20
	212.0	39.33
	509.9	35.19
	1019.8	28.34
	5088.8	15.59
	15297.0	10.86
D888801D52XH	0.0	46.91[a]
	81.2	44.17
	155.5	43.61
	215.5	43.26
	509.9	41.71
	1019.8	39.88
	5088.8	36.99
	15297.0	31.20
D89118X0001H	0.0	62.90[a]
	38.3	51.26
	99.5	46.88
	204.0	34.84
	509.9	23.87
	1019.8	17.74
	5088.8	16.71
	15297.0	11.16
D89118X0002H	0.0	51.51[a]
	82.2	45.82
	158.5	44.57
	217.0	43.72
	509.9	40.81
	1019.8	38.50
	5088.8	35.94
	15297.0	23.74

a. Saturated moisture content.

3.3.7 Saturated Hydraulic Conductivity

Saturated hydraulic conductivity describes the volume of water a substance can transmit under specified conditions. All samples had significant holding times of one to three years. This time may have allowed samples to desiccate or be affected by microbial growth. Older samples also had a greater potential to be physically disturbed prior to analysis.

Two methods were used to determine the saturated hydraulic conductivity of the RWMC sediments: 1) the falling head method and 2) the constant head method. The methods and procedures used are described in Appendix F of McElroy and Hubbell, 1990.

Table 3.3-10 presents comparisons of saturated hydraulic conductivities from samples ST09, D35, D36, and D37 tested for saturated hydraulic conductivity in 1987 and 1988 at the IRC Laboratory. Portions of these samples were reanalyzed in 1989 at the DBS Laboratory. Analyses performed at the IRC Laboratory in 1987 and 1988 showed good agreement between saturated hydraulic conductivities, within a factor of 2.5. Results of tests performed by DBS indicate the same range of values for D36 and D37 but a larger variation in results for samples D35 and ST09.

A comparison of collocated samples D49, D49-2, D90, and D90-2 indicates a significant difference in saturated hydraulic conductivity between samples collected adjacent to each other. Textural differences between collocated samples were observed, based on the particle-size analyses. Collocated samples were tested with both falling-head and constant-head tests. The type of test performed should not affect the results. The results indicate there may be significant differences in measured saturated hydraulic conductivity between samples collected over small distances.

A comparison of the range of hydraulic conductivities found in literature (Freeze and Cherry, 1979) versus the hydraulic conductivities measured from the cores indicates they all fall within the ranges defined for sand, silty sand, silt, and clay (specified as glacial till), except one sample. The hydraulic conductivity for sample D49-2 is anomalously high for silty clay.

Results presented in Table 3.3-10 show a range of saturated hydraulic conductivities from 7×10^{-3} to 1×10^{-8} cm/sec. Collocated samples D49 and D90 show variations of two orders of magnitude. Most of the results are within the range of normal values found in literature.

Table 3.3-10. Comparison of saturated hydraulic conductivities of sediment samples from the RWMC (from Table 13 in McElroy and Hubbell, 1990).

	Hydraulic Conductivity (cm/sec)		
	IRC	IRC	DBS
SampleI.D.	1987	1988	1989
D35	2.2×10^{-3}	3.8×10^{-3}	1.7×10^{-4} [a]
D36	1.9×10^{-2}	1.3×10^{-2}	5.8×10^{-3}
D37	6.4×10^{-3}	1.5×10^{-2}	6.7×10^{-3}
ST09	--	1.0×10^{-2}	1.71×10^{-4}
ST10	--	--	5.96×10^{-5}
ST20	--	--	7.17×10^{-5}
ST06	--	--	4.54×10^{-5} [a]
D89	--	--	5.06×10^{-3}
D90	--	--	3.98×10^{-4}
D90-2	--	--	9.0×10^{-6} [a]
D67	--	--	1.13×10^{-8} [a]
D77	--	--	1.44×10^{-7} [a]
D79	--	--	2.63×10^{-7} [a]
D49	--	--	2.74×10^{-3}
D49-2	--	--	1.17×10^{-5} [a]
D50	--	--	1.30×10^{-4} /
D52	--	--	3.45×10^{-6} [a]
USGS1	--	--	1.85×10^{-4}
USGS2	--	--	2.00×10^{-5} [a]
USGS4	--	--	4.75×10^{-7} [a]

a. Falling Head test. All tests are constant head tests except as noted.

3.3.8 Unsaturated Hydraulic Conductivity

Unsaturated hydraulic conductivity as a function of pressure head and moisture content was calculated for each sample, using a closed-form analytical solution (van Genuchten, 1980) based upon Mualem's (1976) theoretical model. This method is detailed in Appendix F of McElroy and Hubbell, 1990. Parameters for the analytical solution are estimated by using a non-linear least squares numerical procedure applied to measured moisture-retention data.

An additional technique was used for two of the samples, (D90 and D49) to provide a means for comparison of hydraulic conductivity values between methods. The one-step outflow experimental procedure (Gardner, 1976) was performed. A soil column was drained as rapidly as possible by applying a pressure gradient to the sample, and the rate of outflow during drainage was measured. Hydraulic parameters were estimated by fitting curves to the outflow data. Estimated parameters were used to solve for unsaturated hydraulic conductivities using a numerical method developed by Kool et al., (1985). This method is described in Appendix F and the unsaturated hydraulic conductivity parameters, raw laboratory results, and plots are located in Appendix A-7 of McElroy and Hubbell, 1990.

Hydraulic conductivity values, as a function of water content, were compared between those calculated from Mualem's method (1976) and those values determined from the more experimentally based method of Kool (1985). The maximum variation in unsaturated hydraulic conductivities between the two methods was approximately one order of magnitude for samples D90 and D49. The values were most divergent at the drier end of the hydraulic conductivity - water content relationship. The Mualem and Kool methods provide compatible results for these RWMC sediments.

Unsaturated hydraulic conductivities were also determined (using Mualem's method) for collocated samples from the original cores D90 and D49. The collocated samples from core D49 (D49 and D49-2) yielded unsaturated hydraulic conductivities, as a function of water content, with a maximum variation of one order of magnitude. Collocated samples from core D90 (D90 and D90-2) yielded unsaturated hydraulic conductivities, as a function of water content, with a maximum variation of 2.5 orders of magnitude. Comparisons between the collocated samples for D49 and D90 exhibited the largest variations within the driest portion of the unsaturated hydraulic conductivity/water content function.

Differences in calculated unsaturated hydraulic conductivities between collocated samples are not surprising when variations in saturated hydraulic conductivities and moisture-release curves are considered. Large variations between contiguous samples point out the need for measurements based on a more representative scale. Laboratory measurements based on a larger, more representative volumes or field-scale determinations of hydraulic properties would provide more representative estimates of these parameters.

Microbial growth during sample storage probably reduced the unsaturated hydraulic conductivity values obtained for specific water contents. The values probably represent minimum hydraulic conductivities, and should be used with an understanding of this limitation.

Table 3.3-11 is a summary of the calculated unsaturated hydraulic conductivity parameters. Table 3.3-12 is a summary of 95% confidence limits on the calculated α and N values.

Table 3.3-11. Summary of unsaturated hydraulic conductivity parameters (from Appendix A–7, page A-219 of McElroy and Hubbell, 1990).

Sample Number	α cm^{-1}	N dimension-less	θ_r %, cm^3/cm^3	θ_s %, cm^3/cm^3	K_{sat} cm/sec	r^2 dimension-less
D35	0.02256	1.52624	13.26	47.37	$1.07X10^{-4}$	
D36	0.02657	2.59829	3.80	52.01	$5.81X10^{-3}$	
D37	0.03922	2.55351	4.82	44.32	$6.73X10^{-3}$	
ST09	0.01197	1.58911	12.58	51.08	$1.71X10^{-4}$	
ST10	0.00705	1.57561	14.21	49.62	$5.96X10^{-5}$	
ST20	0.01711	1.39785	10.12	47.92	$7.17X10^{-5}$	
ST06	0.00895	1.53556	22.42	45.06	$4.54X10^{-5}$	
D89	0.01241	1.79494	3.85	55.40	$5.06X10^{-3}$	
D90	0.01027	1.69190	15.80	62.22	$3.98X10^{-4}$	
D90[a]	0.01824	1.55319	15.80	62.22	$3.98x10^{-4}$	0.99321
D90-2	0.00502	1.58072	22.17	61.51	$9.00X10^{-6}$	
D67	0.00019	7.24989	37.56	47.24	$1.13X10^{-8}$	
D77	0.00281	1.41289	27.02	46.84	$1.44X10^{-7}$	
D79	0.00196	1.48822	23.36	42.41	$2.63X10^{-7}$	
D49	0.04928	1.29917	19.49	62.04	$2.74X10^{-3}$	0.98469
D49[a]	0.01344	1.36259	19.49	62.04	$2.74x10^{-3}$	
D49-2	0.00285	1.53977	25.83	61.49		
D50	0.00885	1.44697	10.86	51.61	$1.30X10^{-4}$	
D52	0.00634	1.36886	31.20	46.91	$3.45X10^{-6}$	
USGS-1	0.01729	1.61055	11.16	62.90	$1.85X10^{-4}$	
USGS-2	0.01115	1.29978	23.74	51.51	$2.00X10^{-5}$	
USGS-4	0.00575	1.32643	19.58	34.81	$4.75X10^{-7}$	

a. Determined from one-step outflow method. All tests were based upon Mualem's (1976) model, except where noted.

Table 3.3-12. Summary of the 95% confidence limits on the calculated unsaturated hydraulic properties (from Appendix A-7, page A-220 in McElroy and Hubbell, 1991).

	95% Confidence Limits			
	α		N	
Sample Number	Lower	Upper	Lower	Upper
D86D02XD35XH	0.0072	0.0379	1.3171	1.7354
D86D02XD36XH	0.0180	0.0352	1.7457	3.4508
D86D02XD37XH	0.0351	0.0433	2.3018	2.8052
D86W06XST09H	0.0044	0.0195	1.3293	1.8489
D86W06XST10H	0.0041	0.0100	1.4017	1.7495
D86W09XST20H	0.0034	0.0308	1.2342	1.5615
D86W24XST06H	0.0043	0.0136	1.3388	1.7323
D87D10XD89XH	0.0098	0.0150	1.6482	1.9417
D87D10XD90XH	0.0064	0.0142	1.4794	1.9044
D87D10XD90XH-2	0.0033	0.0067	1.4227	1.7387
D87D15XD67XH	0.0001	0.0002	-164.2377	178.7375
D87D15XD77BH	-0.0013	0.0069	1.0409	1.7848
D87D15XD79AH	-0.0005	0.0044	1.0753	1.9012
D888801D49XH	-0.0327	1.1313	1.1086	1.4897
D888801D49XH-2	0.0009	0.0048	1.2584	1.8211
D888801D50XH	0.0002	0.0175	1.1732	1.7207
D888801D52XH	-0.0014	0.0141	1.1128	1.6249
D89118X0001H	0.0079	0.0267	1.3822	1.8389
D89118X0002H	-0.0069	0.0292	1.0650	1.5345

3.3.9 Vertical Air Permeability

Air permeability governs the convective transport of air through the soil in response to a total pressure gradient (Hillel, 1980). Air permeability of unconsolidated sediments is very sensitive to the bulk density and structure of the soil (Klute 1986). Removing samples from the measurement device to change or measure their water content is a potential source of damage to the sample. Air bypassing at sample boundaries, such as from the sample shrinking away from the core sidewalls during drying, also introduces error.

Vertical air permeability measurements were performed on 14 core samples collected from the same original cores as were used for measuring hydraulic properties. Air permeabilities were measured under two different conditions: 1) in-situ water content and 2) in a dry state. Two samples, D50 and D36, were also brought to 50% saturation to determine one more point on the air permeability/water content function.

Air permeabilities were measured by flowing dry nitrogen gas through a sample core contained in an air permeameter under a specified confining stress. The first air permeability measurements were performed at in situ saturation. Water was then extracted from each sample by displacement with toluene to determine the amount of water held by the sample. Bulk volumes were determined by immersion of the soil core in toluene and calculating the displacement. Porosities were determined by flowing helium through the samples. Core samples were oven-dried and air permeabilities were determined for the dry condition. Details of the methods are provided in Appendix G of McElroy and Hubbell, 1990.

Tables 3.3-13 and 3.3-14 lists the summary vertical air permeability results. The air permeability data are in millidarcies (md), where 1 md equals approximately 10^{-11} cm^2. Raw laboratory data are presented in Appendix B of McElroy and Hubbell, 1990.

Table 3.3-14 lists the air permeability for the dry sediments as a function of texture. Samples STO6 and D37 exhibited anomalously high and low (respectively) air permeabilities for the dry condition when compared to other samples of similar texture. Sample ST06 is a clay and desiccation during drying may have provided a short-cut conduit for air flow. Sample D37 is a sand and a high air permeability was expected for the dry state. However, the measured value was an order of magnitude lower than a similar-textured sample from the same borehole.

Weeks (1978) measured the air permeability of surficial sediments from Birch Creek Playa, 28 mi northeast of the RWMC. The sediments consist of clays, silts, and sands. The measured air permeabilities of the RWMC surficial sediments (ST10 and ST20) are within the 100 to 8,000 md range determined for the Birch Creek Playa sediments.

Laboratory determined air permeabilities from the 30-, 110-, 240-, and 560-ft interbeds at the RWMC range from 3.5 to 6443 md. For comparison, a field-determined air permeability of 2,000 md was calculated by Weeks (1978) for a sedimentary interbed located 80 to 104 ft below land surface at the Birch Creek Playa. Generally, the laboratory results underestimate the field air permeability, possibly because of compaction of cores or because of the lack of secondary porosity features in sample cores (Weeks, 1978).

Table 3.3-13. Summary results for vertical air permeability measurements (from Table 14 in McElroy and Hubbell, 1990).

	Vertical Air Permeability (mdarcies[a])			
Sample Number	Dry	50% Saturation	Native State	Native State Moisture Content (% gravimetric)
D35	6440	--	374	27.2
D36	5280	1850	232	28.8
D37	276	--	13	20.9
D77	12	--	<0.1	25.9
D79	14	--	<0.1	21.1
D49	186	--	96	29.5
D50	99	34	21	25.0
D52	3.5	--	0.7	25.0
ST06	8260	--	2570	19.4
ST10	654	--	72	29.6
ST20	3390	--	66	17.9
USGS-1	386	--	244	7.7
USGS-2	104	--	5.7	21.3
USGS-4	19	--	<0.1	25.8

a. One md equals $10^{-11}cm^2$

Table 3.3-14. Air permeability for dry sediments as a function of texture (from Table 15 of McElroy and Hubbell, 1990).

	Air Permeability (md)				
	Clay	Silty Clay	Silt	Clayey Sand Silty Sand	Sand
D35	--	--	--	6440	--
D36	--	--	--	--	5280
D37	--	--	--	--	276
ST06	8260	--	--	--	--
ST10	--	--	654	--	--
ST20	--	--	--	3390	--
D77	--	12	--	--	--
D79	14	--	--	--	--
D49	--	186	--	--	--
D50	--	99.01	--	--	--
D52	--	3.5	--	--	--
USGS-1	--	--	386	--	--
USGS-2	--	104	--	--	--
USGS-4	19.7	--	--	--	--

3.3.10 Conclusion

Subcores of the 19 original sediment cores from the RWMC yielded physical and hydrological information useful to characterization of the subsurface beneath the SDA. Grain-size distribution and particle-density results are representative of in-situ field conditions for all samples. However, a portion of the results of dry bulk density, porosity, moisture characteristics, saturated and unsaturated hydraulic conductivity, and air permeability measurements do not appear to represent in-situ field conditions.

Several factors have contributed to the data limitations. The long storage time of the samples, prior to analysis, yielded in-situ moisture contents, which should be regarded as minimum values. The long storage time facilitated desiccation and microbial growth, which may have influenced hydraulic conductivity measurements. Some of the saturated hydraulic conductivities from these recent analyses were compared to previous hydraulic conductivities determined for the same samples. The results prior to storage and after two years of storage agreed within two orders of magnitude.

In-situ moisture contents for four of the samples (D35, D36, D37, and ST09) were invalid due to prior saturation of the samples in the laboratory.

Other factors which contributed to the data limitations include sample compaction and heterogeneity of the core sample. Sample compaction was evident in some of the samples analyzed for dry bulk density and moisture retention characteristics. Variations in results for collocated samples reflect the vertical heterogeneity within the sediments, and the need for a larger, more representative scale to be used for measurements.

3.4 Miscellaneous Information

Table 3.4-1 is a summary of unsaturated sediment parameter values used in selected modeling studies that have not been covered in other sections of this report. They are presented here for completeness.

Table 3.4-1. Unsaturated zone sediment parameter values used in selected modeling studies.

Saturated Hydraulic Conductivity	van Genuchten α	van Genuchten n	Residual Moisture Content	Porosity	Reference
25 cm/hr	0.0108	1.38	0.06	0.476	Rawson, S. A., J. C. Walton, and R. G. Baca, 1989
23.9 m/y	1.066 m^{-1}	1.523	0.142	0.487	Baca et al., 1992; Rood, 1994
$6.8x10^{-3}$ cm/s	0.194	1.38	0.06	0.476	Rawson, S. A., J. C. Walton, and R. G. Baca, 1991

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